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THE LONELY CHILD

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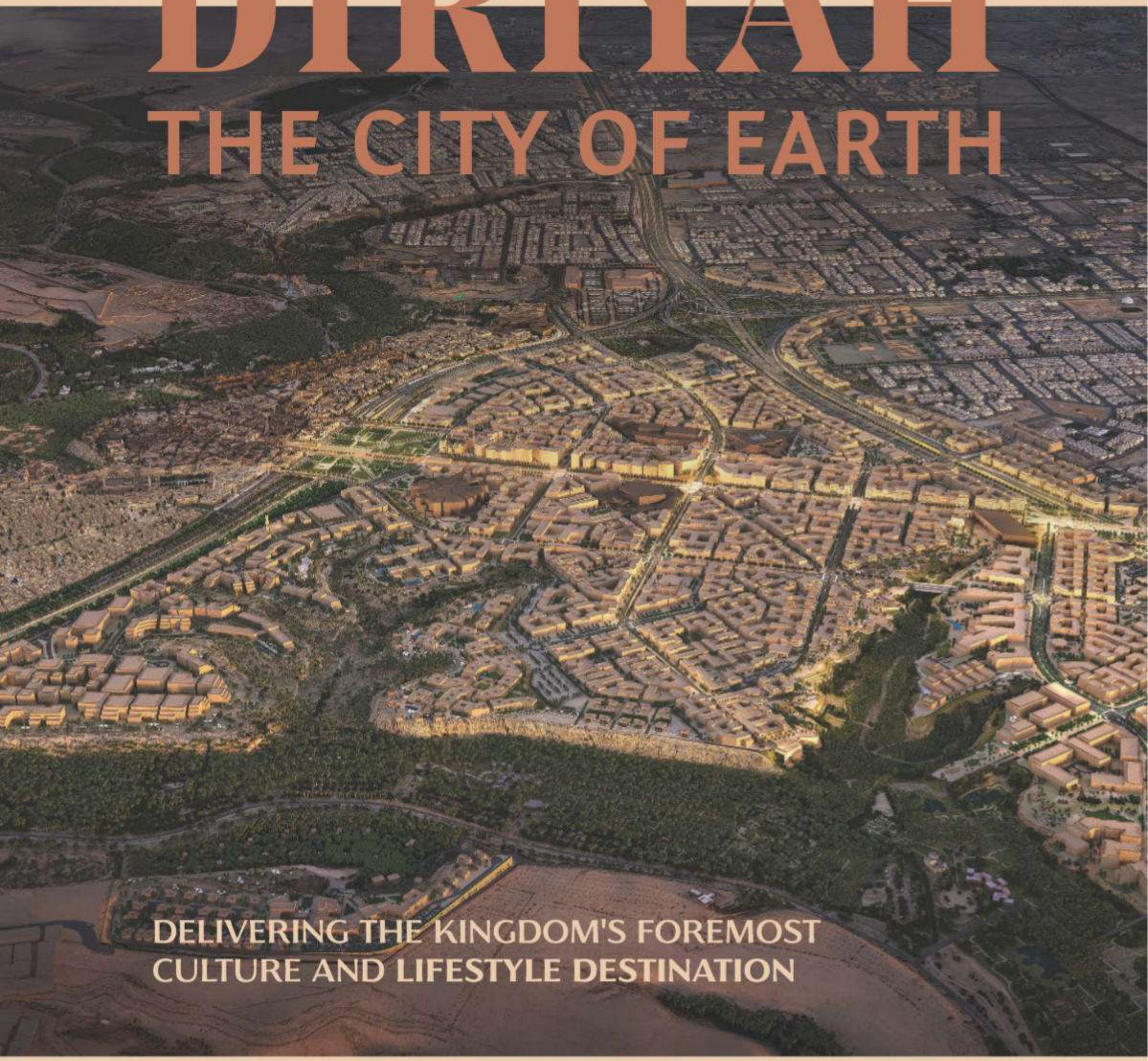

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AI for all

Hear AI expert Neil Lawrence discuss the profound differences between human and machine intelligence and why this means fears of being displaced by AI may be unfounded. Contrasting our evolved, embodied minds with the origins and limitations of AI, he reveals how these tools can and should be wielded by ordinary people. Find out more on 13 October at New Scientist Live, either online or in person at London's ExCeL Centre.

newscientist.com/nslmag

Tour

Astronomy in Kepler's Prague: Czech Republic

Join space scientist and historian Martin Griffiths on a journey to the heart of Renaissance astronomy. Explore Prague's medieval marvels and walk the streets as Johannes Kepler and Tycho Brahe would have in the city of 100 spires. This six-day tour starts 14 September 2025.

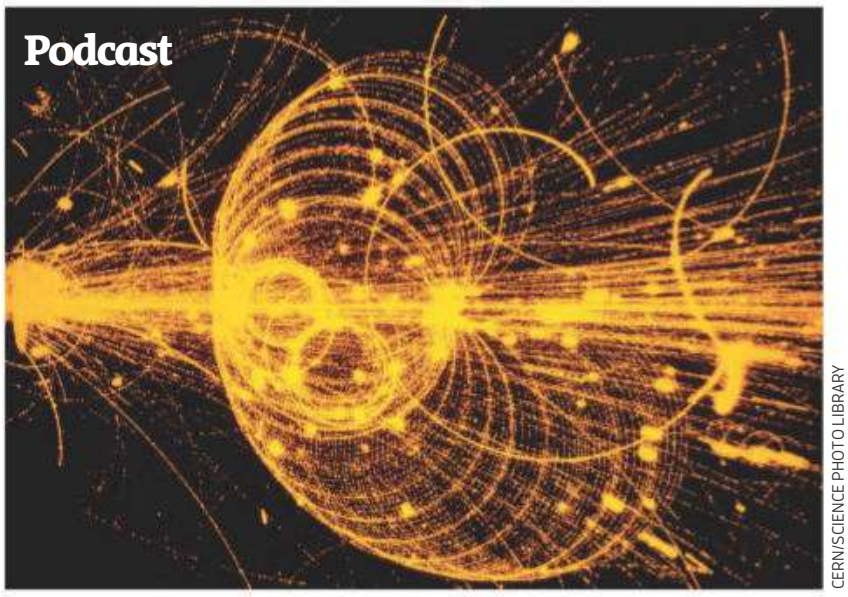
newscientist.com/tours

Podcast

CultureLab

Physicist Carlo Rovelli originated the relational interpretation of quantum mechanics, which posits that the fundamental building blocks of the universe aren't particles or objects but the relationships and interactions between them. Rovelli explains why he thinks we should apply this idea to our everyday lives and relationships – and how it could even help to improve international cooperation.

newscientist.com/nspod



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Quantum interactions Are relationships the base units of reality?

STEPHEN FILMER

Eye to eye Human ancestor Lucy rewrote the story of our evolution

Video

Unearthing Lucy

Palaeoanthropologist Donald Johanson looks back on his discovery of the early hominin Lucy in Ethiopia in 1974. This 3.2-million-year-old skeleton shifted our understanding of human evolution. "We knew that because it was so complete it was important, but I didn't realise it would actually launch a new species," says Johanson.

youtube.com/newscientist

Newsletter

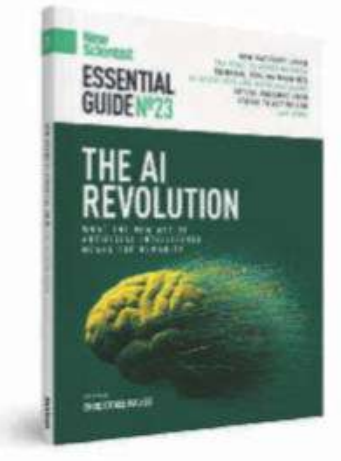
Lost in Space-Time

Writer Steve Nadis and mathematician Shing-Tung Yau have released a new book called *The Gravity of Math*. In it, they outline their case that mathematics isn't just the language of science but also the driver of some of our biggest discoveries – including the detection of gravitational waves.

newscientist.com/lost-in-space-time

Newsletter

"Albert Einstein had profound doubts as to whether gravitational waves truly existed"



Essential guide

Tools such as ChatGPT have put artificial intelligence on front pages around the world. So why has AI leapt forwards so suddenly? How can generative AI tools help you? And will this tech lead to human extinction? Get the lowdown on all this and more in our new *Essential Guide*, on sale now.

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A beacon of hope

Critics of the ageing International Space Station are missing the point

THE International Space Station (ISS) is reaching the end of its life, with agencies around the world planning for its demise in around 2030. This orbiting behemoth has been continuously occupied for nearly 24 years by astronauts and cosmonauts from the US, Russia, Europe, Japan, Canada and many other regions, but it is getting old. It is nearly time to bring it down (see page 36) before its ageing parts take it out in a much more dangerous way.

The endeavour of keeping such a huge laboratory in orbit has been controversial, with some saying that it has been a waste of money or that it should have been deorbited long ago. Critics claim it hasn't lived up to all of its promises and the scientific results from studies on the station haven't done enough to help matters on Earth. Those criticisms may or may not be true, but they are missing the point.

The ISS, as a global collaboration on a very difficult venture in space, has always represented the possibility of a better world, one of peace and cooperation. Its two primary stakeholders, the US and Russia, have long been at odds on the ground, but that hasn't deterred astronauts and cosmonauts from working together aboard the station in an effort to increase global knowledge and reach into the solar system. It is a symbol of humanity striving towards a common goal.

"Once the ISS goes, we are vanishingly unlikely to see anything like it again"

Once the ISS goes, we are vanishingly unlikely to see anything like it again. NASA and other space agencies are focusing on the moon, and the possibility of building an international astronaut village there, while an exciting prospect, is a pipe dream for now. Our prime example of international cooperation will burn up in the atmosphere and plunge into the ocean, and that loss will resonate beyond space science. It represents a withering of global collaboration, just the sort of thing we need to meet the grand challenges the world is facing now, such as climate change – and that is a loss we should all lament. ▮

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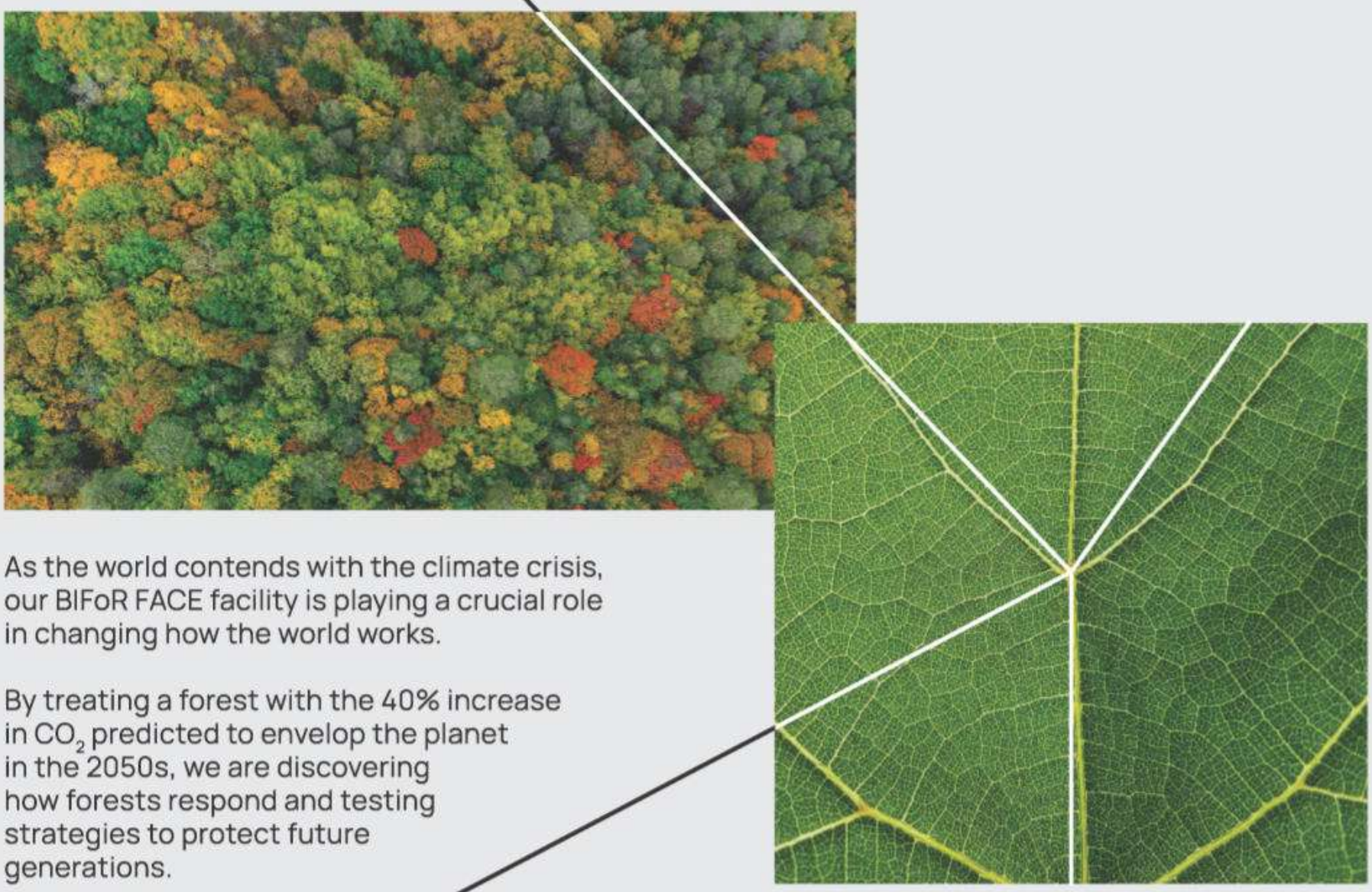
Revealing the effects of climate change on forests of the future



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Go with the flow
An AI is setting speed limits on a US freeway **p19**

FABRIZIO VILLA/GETTY IMAGES

Earth science

Etna unleashes explosive eruption

Huge plumes of ash and fountains of lava have been spewing from Mount Etna on the Italian island of Sicily, seen here from the port of Ognina. The activity of Europe's tallest volcano has got fiercer after several weeks of eruptions, showering surrounding areas with ash and causing flight cancellations. Italy's National Institute of Geophysics and Volcanology says there are ongoing lava flows from two of Etna's craters.

Cosmology

‘Banana’ galaxies unpeel a mystery

Strange, banana-shaped galaxies spotted by astronomers seem to take this form because of filaments of dark matter, finds **Alex Wilkins**

A SURPRISING number of distant, banana-shaped galaxies spotted by the James Webb Space Telescope (JWST) could be tracing a vast web of dark matter from the universe’s first moments, and may even be a sign of strange kinds of dark matter. Working out which types could help us understand how galaxies across the universe formed.

Astronomers assume that most galaxies start out as fairly symmetrical discs before evolving into more complex swirls like our own Milky Way. However, in the 1990s the Hubble Space Telescope started spotting elongated, or what astronomers call prolate, galaxies in the early universe that didn’t fit with this picture.

Many researchers thought this might be a result of Hubble’s view of the scene – it was only seeing the brightest galaxies, which could either be prolate or discs seen from the side, and missing the dimmer disc galaxies that are orientated face-on to Earth.

People also suggested that the gravity from massive galaxies between the distant galaxies and us might be distorting the light coming from the far-off ones to make them appear more elongated, an effect called gravitational lensing. But some astronomers proposed that dark matter, an invisible particle or force that exerts a powerful gravitational pull, might be responsible.

“If that is the correct solution, that just throws our galaxy formation theories into disarray”

Last year, Viraj Pandya at Columbia University in New York and his colleagues started spotting many more of these elongated galaxies with JWST, which they called “banana galaxies”, in the early universe between 8 billion and 13 billion years ago. JWST is much more sensitive than Hubble and should be able to see the face-on disc galaxies if they exist. But the normal disc galaxies seemed to still be missing.

“At a certain point, you have to throw your hands up and say, ‘Well, OK, maybe this is really a fundamental puzzle’,” says Pandya.

Now, he and his colleagues have calculated that gravitational lensing wouldn’t produce enough of an effect to elongate these galaxies so much, which strengthens the picture that these aren’t disc galaxies seen from an odd angle. “If that is the correct solution, that just throws our galaxy formation theories into disarray,” says Pandya.

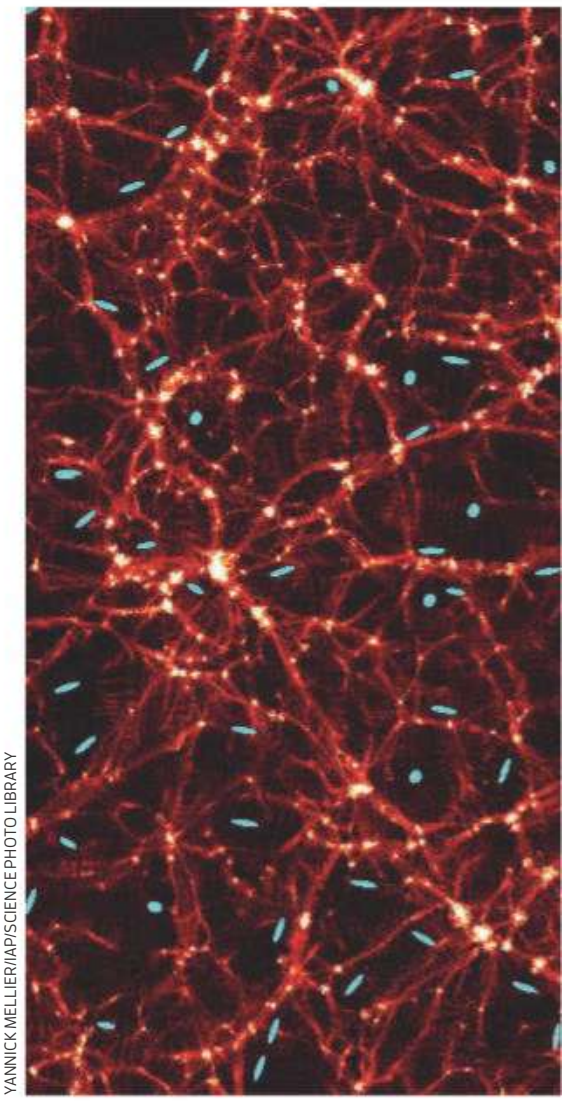
The researchers also analysed whether the galaxies were pointing in random directions or whether they lined up in any sort of pattern. To do this, they took different pictures from JWST of the same patch of sky and measured the average orientation across all of them.

If the galaxies were randomly orientated, their average orientation should be zero, but instead the researchers found that the galaxies were statistically aligned (arXiv, doi.org/nbqd).

This could be because some dark matter we don’t know about is sitting between us and the galaxies and is aligning them, but we don’t know of any large galaxy clusters, which themselves contain dark matter, that might be responsible in these regions of the sky, says Pandya.

Following the threads

Another explanation could be that these galaxies are actually forming along filaments of dark matter in the early universe, revealing the complex structure of the young cosmos that is otherwise invisible (see “The dark matter web”, left).



YANNICK MELLIER/IAP/SCIENCE PHOTO LIBRARY

The banana-like shape of some galaxies (inset) may be due to the universe’s hypothesised web of dark matter (illustrated above)

“These elongated galaxies could be like little light bulbs and they’re tracing out the filaments,” says Pandya. However, we will need to calculate more accurate distances to these galaxies before we can distinguish between the two scenarios, he says.

The dark matter filaments that may be responsible for these elongated galaxies could also be exotic in nature. In another study, Álvaro Pozo at the University of the Basque Country in Spain and his colleagues have run simulations of the early universe to see what shape the galaxies

The dark matter web

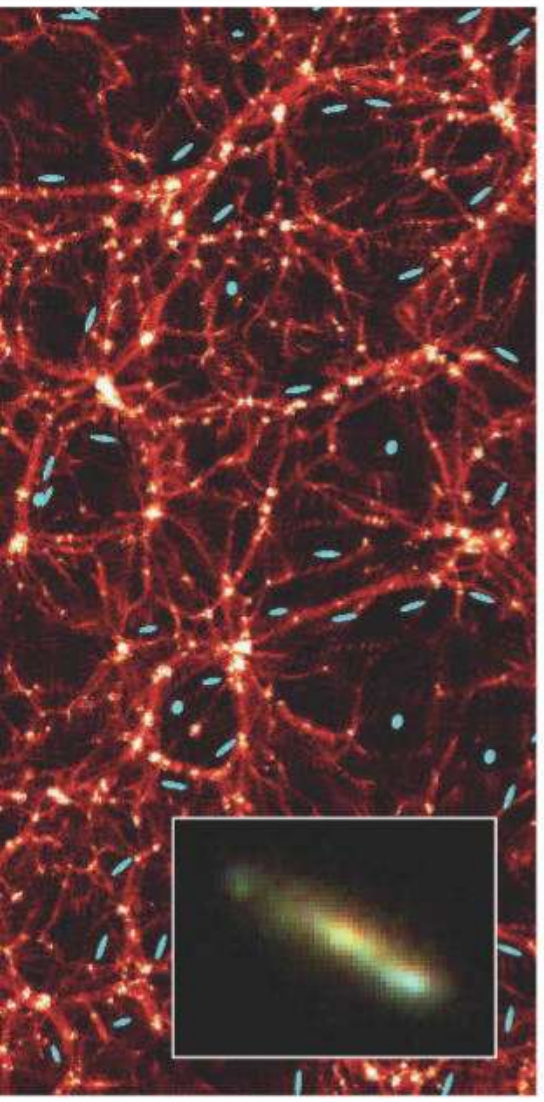
We know that galaxies and dark matter go hand in hand. While we can’t see dark matter using light, we can observe it through its gravity, which affects the structure and movement of galaxies across our universe.

Astronomers have mapped out this dark matter by looking at nearby galaxies and found a vast web of filaments connecting different clumpy regions.

Charting these filaments in the early, distant universe is much more difficult because we can’t accurately measure how far away the galaxies are. Our current best method is to use far-off and bright black holes called quasars as flashlights to illuminate slightly closer regions of the universe, but we don’t know if these areas are representative of the entire web.

Tracing the alignments of banana galaxies (see main article) might provide an alternative way to chart this dark matter, which is crucial for our understanding of cosmology.

By mapping out basic properties about these filaments, such as their number, length and thickness, we can build better cosmological models and find out which theories best match up to reality, says Viraj Pandya at Columbia University in New York.



would form, and at which times, according to different models of dark matter.

They tested what would have happened with cold dark matter, the slow-moving and inert dark matter particle that factored in to the standard cosmological model; warm dark matter, where particles

"These elongated galaxies could be like little light bulbs and they're tracing out the filaments"

are faster-moving; and wave dark matter, where particles are smeared out across space like ripples on a lake.

Pozo and his colleagues found that cold dark matter only produced elongated galaxies at much earlier times in the universe's history than those identified by Pandya. But the warm and wave dark matter simulations produced strikingly similar galaxy patterns of the same age as those spotted by Pandya's team (arXiv, doi.org/nbqf).

Riddles in the dark

If we can work out what form dark matter takes, then we can understand how and when galaxies and the large-scale structure of the universe form, says Claudia Maraston at the University of Portsmouth, UK. In cold dark matter, for instance, structures form from the bottom up. Galaxies group together, then groups themselves form clusters, until the universe's structure is determined. But in warm dark matter, the large-scale structure determines the formation and behaviour of smaller objects, like galaxies.

Finding possible evidence of dark matter filaments and verifying that these galaxies really do have these elongated shapes is very exciting, says Maraston. But we have only seen a small number of prolate galaxies with JWST so far and will need to observe many more with both JWST and future galaxy surveys, such as the European Space Agency's Euclid telescope, before we can be sure that there aren't still observational biases, she says.

The galaxy simulations from Pozo and his team produce convincingly similar images to what physicists observe, but the simulation only runs to relatively early in the universe's history, says Maraston. To convince astronomers that warm or wave dark matter is correct, the simulations will also have to reproduce what we see in our most recent universe, she says. ▮

Environment

Rising land under Antarctica could slow sea level rise

James Dinneen

WE COULD see a slowdown in ice loss and reduction in sea level rise in coming centuries thanks to the lifting-up of land beneath Antarctica's ice sheet. However, if emissions continue to go up, the effect may flip and accelerate sea level rise instead.

As melting ice reduces Antarctica's weight, the mantle – the layer below Earth's crust – rebounds, raising the land above it. The rebounding land may then slow the ice sheet's flow where it meets the sea. This is thought to happen because the land reshapes the seabed in a way that limits the thickness of the ice sheet at its edge – and thinner ice there reduces the flux of ice into the sea.

Researchers have long thought the effect would play a role in slowing ice loss. But it wasn't clear when it would kick in, or how it might vary.

Now, Natalya Gomez at McGill University in Canada and her colleagues have modelled the relationship between the ice and rebounding land, including a simulation of the mantle that captured differences in viscosity beneath the continent.

East Antarctica sits above a more viscous mantle and thicker crust, while West Antarctica's rapidly melting glaciers lie atop a less viscous mantle and thinner crust. We know this based on decades of measurements of changes in the elevation of the ice sheet, plus data about the mantle below Antarctica from seismic waves produced by earthquakes.

Under a very low-emissions scenario, the researchers found that rebounding land reduced Antarctica's contribution to global average sea level rise by over half a metre by 2500, compared with a model that treated the ground as rigid. This effect was less significant under a moderate-emissions scenario, but it still led to a substantial reduction in sea level rise, which kicked in as soon as 2100.

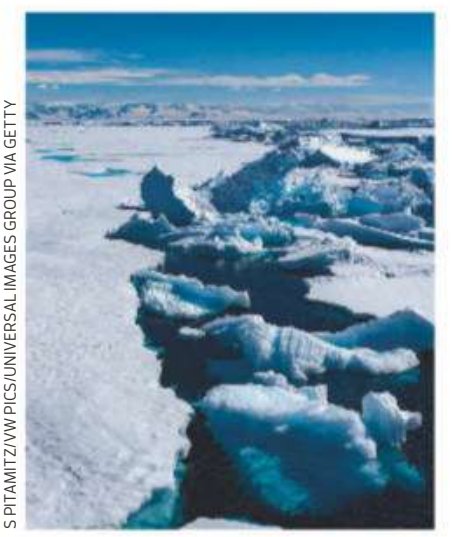
>0.5m

How much sea level rise could be reduced by if emissions stay low

However, under a high-emissions scenario, that rebounding land led Antarctica to contribute an extra 0.8 metres to sea level rise by 2500. This happened because the ice sheet receded faster than the land rebounded, and the rising seafloor displaced more water into the rest of the ocean (*Science Advances*, doi.org/nbp9).

"From a modelling perspective it's a very big advance," says Alexander Bradley at the British Antarctic Survey. Rebounding land was always assumed to reduce sea level rise, but this modelling shows that the effect depends on emissions, he says. "The changes that take place in the 21th and 22nd century are really baked in by what we do now." ▮

An ice shelf on the Weddell Sea, Antarctica



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Archaeology

Smallest adult hominin ever found

An arm bone from an ancient human that lived 700,000 years ago adds a new piece to the puzzle of *Homo floresiensis*, the so-called hobbits that lived on the island of Flores, finds **Michael Marshall**

ANCIENT humans living on an Indonesian island 700,000 years ago were even smaller than *Homo floresiensis*, the so-called hobbits that lived on the same island much more recently. Newly analysed fossils may represent the hobbits' ancestors – but the evolutionary story of these small-bodied hominins is still shrouded in mystery.

Fossils of *H. floresiensis* were first discovered in 2003 in Liang Bua cave on the island of Flores. The bones date from between 90,000 and 50,000 years ago.

In 2016, Yousuke Kaifu at the University of Tokyo and his colleagues uncovered hominin remains from Mata Menge, an open-air site further east on Flores that was once a riverbed. The remains are about 700,000 years old and include part of a skull, a piece of jawbone and six teeth, all unusually small for a hominin.

The obvious interpretation was that the Mata Menge hominins were the ancestors of the hobbits. But because the remains were so fragmentary, it wasn't possible to say for sure.

Kaifu and his colleagues have now described three new remains from Mata Menge: two teeth and, crucially, a piece of an upper arm bone, or humerus. With this limb bone, "we could finally determine the body size", says Kaifu.

Unfortunately, the humerus isn't complete: the shaft is snapped. To determine how far along the break occurred, the team looked for key markers, including a groove that supports a nerve and the attachment point for a muscle. They determined that the bone had broken about halfway along, enabling them to estimate its total length as between 20.6 and 22.6 centimetres.

There are telltale features of the microstructure of the bone that confirm it is from an adult. Extrapolating from the humerus to the entire body, the team estimates the Mata Menge

"Flores was home to dwarf elephants and other species that had shrunk over many generations"

hominin was between 93 and 121 cm tall, with a best estimate of 100 cm. That is a little shorter than the *H. floresiensis* specimens from Liang Bua – which Kaifu says were at least 6 cm taller – making it the smallest adult hominin ever discovered (*Nature Communications*, DOI: 10.1038/s41467-024-50649-7).

The findings point to a likely explanation for the evolution of *H. floresiensis*, says Kaifu. It has long been suspected that the species was descended from larger hominins called *Homo erectus*, which are the first hominin species known to have lived beyond Africa – including on Java in Indonesia about a million years ago. "I'm almost sure that they are derived from those populations," says Kaifu. This is because of similarities between the teeth from Mata Menge and those of *H. erectus* from Java, and the close proximity of the dates and locations.

The suggestion is that a small population of *H. erectus* reached Flores, possibly by accident, and lived there in isolation. They must have then evolved a smaller body size within 300,000 years, says Kaifu. "They were small early and then they remained small for a long, long time," he says.

It is common for island-dwelling animals to shrink through evolution because food resources are limited and the lack of large predators means there is no advantage to being bulky. In line with this, Flores was home to dwarf elephants and other species that had shrunk over many generations.

However, there are alternative explanations, according to Debbie Argue at the Australian National University in Canberra, author of *Little Species, Big Mystery: The story of Homo floresiensis*.

Argue points out that the Mata Menge teeth don't look especially similar to the *H. floresiensis* teeth from Liang Bua. For instance, a molar from Mata Menge has five pointed "cusps" – *H. floresiensis* molars have four. "There's no clear indication of anyone evolving into anyone else," she says, and it isn't obvious why *H. floresiensis* would have evolved slightly larger bodies than their Mata Menge ancestors. Furthermore, "there's no evidence for *Homo erectus* from the island", she says.

For these reasons, Argue says we shouldn't assume that the Mata Menge hominins are the ancestors of the hobbits. "I would be considering another hypothesis, that the Mata Menge hominins are a new unknown species." If island life could make one hominin population evolve smaller bodies, it could do so twice, she says.

In 2017, Argue and her colleagues compared *H. floresiensis* with other hominins and concluded that their closest known relatives weren't *H. erectus*, but an older species called *Homo habilis*, which is known only from Africa. On this basis, they proposed that *H. floresiensis* evolved in Africa, from the same ancestral population that gave rise to *H. habilis*. Later, some of them migrated east, ending up on Flores. Argue says we probably need more fossils to resolve the question of the hobbits' origins. ▮

YOUSUKE KAIFU

The fragment of Mata Menge humerus (left) alongside that of *Homo floresiensis*

Health

Keto diet does help fat loss but also raises levels of bad cholesterol

Carissa Wong

EATING a ketogenic diet, which entails getting most of your calories from fat, does lead to fat loss, but may also clog arteries and damage the gut microbiome.

Also known as a keto diet, this way of eating forces the body to rely on ketone bodies – which the liver produces from stored fat – rather than glucose from carbohydrates for fuel, which leads to weight loss.

Previous studies have tracked health outcomes in people who follow a keto diet and suggested it has both harms and benefits.

Now, Javier Gonzalez at the University of Bath, UK, and his colleagues have carried out a randomised controlled trial, the best kind of medical evidence.

The researchers recruited 53 people with an average age of 34, none of whom was obese. They randomly assigned roughly a third to eat a keto diet, in which carbohydrates made up less than 8 per cent of their energy intake and fat constituted more than 70 per cent.

Another third of participants ate a low-sugar diet, where "free" sugars – a type of carbohydrate found in foods such as syrups and biscuits – made up 5 per cent of their energy intake, while their non-free-sugar carbohydrate and fat intakes were 45 per cent and 35 per cent, respectively.

The remaining third ate a diet with moderate levels of free sugars, making up just under 20 per cent of their energy intake, while their non-free-sugar carbohydrate and fat intakes were around 30 per cent and 35 per cent, respectively. These participants acted as the control group. Protein consumption was between 15 and 18 per cent across all of the diets.

Keto diets involve getting most of your calories from fat

SHUTTERSTOCK/GEORGE DOLGIKH

A month later, those on the keto diet had lost 1.6 kilograms of fat, on average. People on the low-sugar diet lost 1 kg of fat, on average, while those on the moderate diet lost no fat. Movement monitors revealed that the fat loss wasn't from exercising more, so resulted from consuming fewer calories, says Gonzalez.

Despite the greater fat loss, those in the keto group had 16 per cent higher levels of low-density lipoprotein (LDL) "bad" cholesterol than those in the control group. They also had 26 per cent higher levels of a protein called apolipoprotein B, which clogs arteries, raising the risk of heart-related events (*Cell Reports Medicine*, doi.org/nbvn).

People on the keto diet also had lower levels of gut bacteria called *Bifidobacterium* than those in the control group. These help produce B vitamins and have been linked to a stronger immune system. This is probably because those on the keto diet ate less of the fibre that would have boosted levels of *Bifidobacterium*, says Gonzalez.

Long-term research is required to determine if a keto diet's weight-loss benefits outweigh potential concerns about cholesterol and gut health, says Natasha Schoeler at Great Ormond Street Hospital in London. Ultimately, the main challenge of losing weight is adhering to a diet, she says. "If you stick to it, generally, you will lose weight." ▮

Ecology

Streetlights may make leaves tough for insects to eat

URBAN trees lit by streetlights tend to have tougher leaves that are eaten less by insects than trees that see dark nights. This could have a detrimental effect on biodiversity.

Shuang Zhang at the Chinese Academy of Sciences and his colleagues have collected about 5500 leaves from 180 trees at 30 sites in Beijing. The trees were of two species: Japanese pagoda (*Styphnolobium japonicum*) and green ash (*Fraxinus pennsylvanicaa*). Some trees were near sodium streetlights and others were growing where nights are dark.

The researchers measured the size, toughness, water content and nutrient levels of the leaves. They also recorded any evidence of insect damage. Leaves from under streetlights were tougher and had less insect damage. On Japanese pagoda trees, the amount of leaf damage was 2.1 per cent in areas with streetlights and 5.3 per cent in dark areas, while the amount of leaf damage on green ash trees was 2 per cent near streetlights and 4.1 per cent in dark areas.

The researchers write that a decrease in leaves eaten by insects will mean less energy flowing up the food chain to insects and birds, leading to a cascading effect that reduces biodiversity (*Frontiers in Plant Science*, doi.org/nbp8).

The mechanism leading to lower leaf damage isn't understood. It could be that more light makes insects more visible to predators, reducing their numbers and their effect on trees, for example.

"It could be that more light makes insects more visible to predators, reducing their effect on trees"

Owen Lewis at the University of Oxford says the study is interesting but doesn't show a causal link. He says measuring herbivory is complex: more damage may mean a leaf has lower nutritional value and insects have to eat more. Holes eaten by insects can also expand as the leaf grows, he says. "My hunch is that this could be quite a subtle effect," he says. The impact of light pollution is likely to be trivial compared with how urbanised the area is or pollution levels, he says. ▮

Matthew Sparkes

Health

Bacteria originally found in faeces help chronic wounds heal

Rohini Subrahmanyam

AN OPEN wound is a playground for bacteria – but some of them are actually helpful. Researchers have found that *Alcaligenes faecalis* – so named because it was first discovered in faeces – promotes the healing of chronic wounds.

In people with diabetes, the process of wound healing collapses, leading to chronic injuries that refuse to mend. These are hard to treat, and can cause painful infections that lead to amputations or even death.

Ellen White at the University of Pennsylvania and her colleagues spotted *A. faecalis* when studying the microbiome of wounds. At first, it seemed like a "bystander" that had no effect. But they repeatedly found that when they colonised wounds with this bacterium, they healed faster. "That was a very surprising finding," says White.

The researchers added *A. faecalis* to injuries on diabetic mice and to human skin samples from people with diabetes. In both cases, compared with untreated controls, the treated wounds and skin samples produced more, faster-moving keratinocytes – a skin cell involved in wound closure (*Science Advances*, doi.org/nbp7).

White and her colleagues also found that the bacterium decreases levels of enzymes that inhibit proper healing, called matrix metalloproteinases (MMPs). Levels of MMPs are higher in people with diabetes, so by rebalancing these enzymes, the bacterium may be restoring the ability to heal.

Swathi Balaji at Baylor College of Medicine in Texas says more work is needed before this can be used as a treatment, because chronic wounds contain a complex variety of interacting bacteria. "If you target one thing, the pathogens will find a way to circumvent it again," she says. "You have to tackle it from multiple different angles." ▮

Climate change

Andean glaciers probably at their smallest size for 130,000 years

Michael Le Page

EVAN VEGA/THE OHIO STATE UNIVERSITY

A researcher sampling exposed rock in front of Queshque glacier, Peru

GLACIERS in the Andes in South America have shrunk to what is almost certainly the smallest they have been for at least 130,000 years.

"This shocked us, frankly," says Andrew Gorin at the University of California, Berkeley. "This is clear evidence that at least one region in the world has now departed the hospitable climatic conditions that have fostered the development of human civilisation."

The Andes mountain range is so high up that there are permanent glaciers in many places, even in tropical areas. It has been clear for decades that these glaciers are thinning and retreating as a result of global heating. But how this compares with what happened in the distant past hasn't been clear.

Gorin and his colleagues have analysed 20 samples of rock that were recently exposed due to the retreat of four tropical glaciers in the Andes. They looked for isotopes of carbon and beryllium that form when exposed rock is hit by cosmic rays, which can reveal when a glacier last retreated past a certain point.

Similar studies in northerly regions of the world have shown that glaciers there were at their smallest a few thousand years ago, around the middle of the current interglacial period.

The researchers expected to find something similar in the Andes at that time, yet levels of the isotopes were so low that they were almost undetectable (*Science*, doi.org/nbp6).

90%

Proportion of ice expected to be lost from glaciers by 2100

"This is an alarm bell. It's the canary in the coal mine for mountain glaciers everywhere," says Gorin. The findings show directly that these glaciers didn't retreat as far as they have today at any time in the past 11,700 years. Before this point, there was a global glacial period, and studies by other teams show that the tropics were cooler then.

While the study doesn't say this, Gorin agreed when asked that this means Andean glaciers have almost certainly shrunk to the smallest they have been since at least the previous interglacial, around 130,000 years ago.

"I'd bet my life savings that your assertion that these glaciers are now the smallest they've been since the last interglacial is true," he says. "However, due to the limitations of the technique we used to address this question, we can't definitively prove that fact, and this is why we don't say so in the article."

"This is a shocking piece of research," says Liam Taylor at the University of Leeds in the UK. "Undoubtedly, the science is conclusively showing that glaciers across the Andes are in a state that they haven't been in since before the Holocene began 11,700 years ago, and this is directly caused by human activities changing the climate."

The retreat of glaciers is affecting farming, drinking water supplies and hydropower in the region, says Taylor. This is because glaciers act as reservoirs, storing winter snowfall and releasing meltwater in the summer. "Many of the glaciers in this region have now passed 'peak water', meaning that meltwater that supplies freshwater downstream is drying up," he says.

Climate models suggest that mountain glaciers will lose more than 90 per cent of their ice by the end of the century, says Stephan Harrison at the University of Exeter, UK, leaving just a few small glaciers in the highest areas. ▮

Technology

The downside of chat

Using chatbots or voice assistants to find out information makes it less likely you will spot errors

Chris Stokel-Walker

THE conversational tone of an AI chatbot or voice-based assistant seems like a good way to learn new concepts, but they may actually make us more willing to believe inaccuracies, compared with information presented like a static Wikipedia article.

To investigate this issue, Sonja Utz at the University of Tübingen, Germany, and her colleagues asked about 1200 participants to engage with one of three formats.

The first involved text appearing letter by letter in the style of a large language model, similar to OpenAI's ChatGPT; the second provided information through a voice-based device like Amazon's Alexa; and the third was a static, text-based copy of Wikipedia.

In all cases, participants weren't able to interact with the systems as they might with the real versions, in order to keep the experience consistent across the study, but they were presented with the real brand names.

In some cases, participants were given accurate information, while others saw factual errors of the kind that can be produced by large language models. Some of these errors were plain wrong, such as naming Sofia as the capital of Slovenia, but others were merely internally inconsistent, meaning a statement was contradicted elsewhere in the same response.

"Humans seem to be hardwired to assign credibility to things that seem lifelike"

Participants were asked to rate the accuracy, trustworthiness and believability of the information on a seven-point scale, where 7 is entirely accurate. In the answers where errors were introduced, information presented in a static, text-based format was rated as 4.24 on average. The ChatGPT-like set-up managed 4.76, while the voice assistant scored 5.29.

Participants rated all of the systems higher for answers where no errors were introduced, but the differences were smaller for the voice assistant and chatbot, suggesting people found it more difficult to identify errors in these formats (*Scientific Reports*, doi.org/nbp5). "It has this dialogic presentation, which is why you tend to believe it," says Utz.

"It's long been understood that people are easily convinced that objects that display or mimic lifelike qualities are in fact alive," says Mike Katell at the Alan Turing Institute, UK. "It's not surprising that people find conversational chat agents more convincing and credible than static text because humans seem to be hardwired to see life where it doesn't exist and to assign credibility to things that seem lifelike."

The way the chatbots and voice agents are programmed to use a friendly and helpful conversational tone also confuses people, says Katell. "The makers of chatbots aren't necessarily trying to deceive us, but they are trying to put users at ease. The goal of a large language model is 'plausibility' and that is achieved through believable content and inoffensive – if not soothing – delivery."

Utz says it is important to recognise that the presentation of information can make a difference to how much we believe it. "People now have learned that these models hallucinate sometimes," she says. "But what people do not know yet is that just this interaction mode makes us more prone to believe whatever is written there. That should be in media literacy training." ▮

Zoology

The upside-down secrets of the sex lives of frogs

CHARLES Darwin's frogs mate upside down, while clinging inside tree cavities. This inverted addition to the Kermit Sutra may help the frogs kick away male competitors.

Sathyabhama Das Biju and Sonali Garg, both at Harvard University, and their colleagues have been studying the mating habits of the Charles Darwin's frog (*Minervarya charlesdarwini*) in the forests of South Andaman Island in the Indian Ocean. Between 2019 and 2022, they recorded and analysed calls and filmed breeding behaviour, which happens in hollows in trees rather than in the puddles or ponds that their close relatives use.

S. D. BIJU

Charles Darwin's frogs are found on the Andaman Islands in the Indian Ocean

During mating, the male grasps onto the back of the female in amplexus, a manoeuvre common in frogs that can last hours to days. Wearing the male like a backpack, the female crawls up and out of the pool, turning around. Upside down and backing up, she then lays her gelatinous eggs along the inner wall of the tree. When the tadpoles hatch, they plop into water below, which gathers in the tree cavities (*Breviora*, doi.org/nbp4).

No other frog is known to breed this way, says Biju. The upturned pose may have evolved to help the frogs deal with aggressive, unpaired males in the tree hole pools. Such males will bite and kick each other in competition for mates, and will try to pry apart mating pairs.

"She just turns upside down and lays [the eggs] up there where there are no males," says Garg. Pointing her rear upwards may also make removing her mate more difficult for challengers.

John Gould at the University of Newcastle in Australia wonders if the female turns upside down so she can see where her offspring are likely to drop after hatching. It might improve the chance her offspring fall directly into the water, he says. ▮

Jake Buehler

Solar system

Can we make a lunar backup of life?

Permanently shadowed regions on the moon would be ideal for preserving deep-frozen organisms

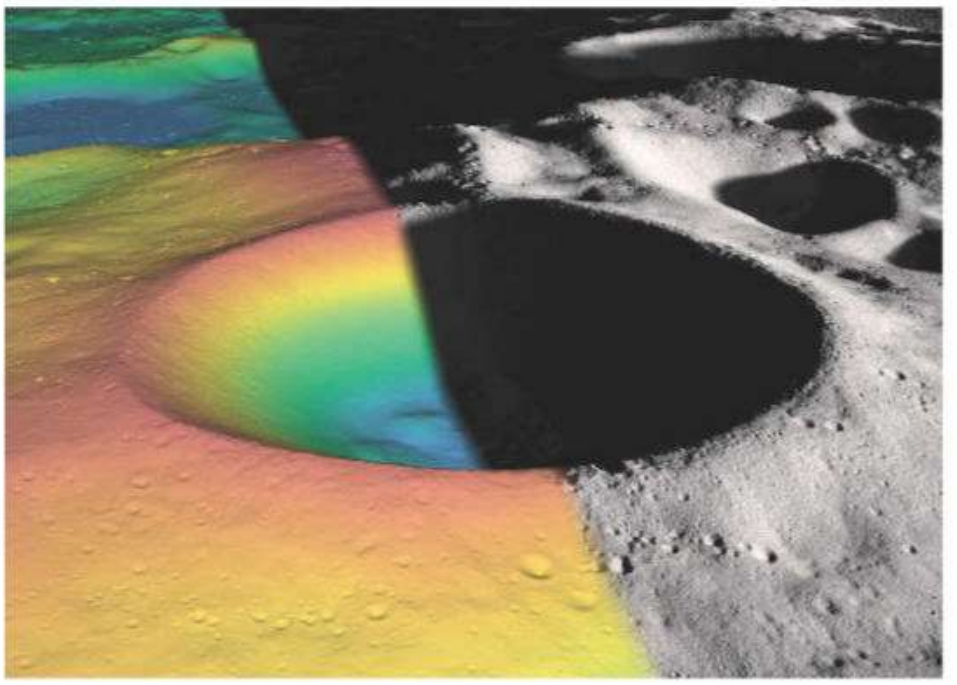
James Woodford

A BACKUP of life on Earth could be kept safe in a permanently dark location on the moon, without the need for power or maintenance, allowing us to potentially restore organisms if they die out.

Mary Hagedorn at the Smithsonian's National Zoo & Conservation Biology Institute in Washington DC and her colleagues have proposed building this lunar biorepository as a response to the extinctions occurring on Earth.

The plan has three main goals: to safeguard the diversity of life on Earth, to protect species that might be useful for space exploration, such as those that could provide biomaterials for food or filtration, and to preserve microorganisms that may one day be needed for terraforming other planets.

Hagedorn says the team wanted to identify a location where no people or energy would be required to keep cryogenically frozen, living cells colder than -196°C – the temperature at which nitrogen is a liquid and all biological processes are suspended.



NASA/ZUBER, M.T. ET AL., NATURE, 2012

Shackleton crater – part coloured to show terrain height – has areas that never see light

"There is no place on Earth cold enough to have a passive repository that must be held at -196°C, so we thought about space or the moon," says Hagedorn.

She says the team settled on the lunar south pole due to its deep craters with permanently shadowed and cold regions (*BioScience*, doi.org/nbg3). Burying samples about 2 metres below the surface would also keep them safe from radiation, she says.

Previous attempts at building secure biorepositories have had mixed success. The Svalbard Global Seed Vault in Norway lies in the Arctic and was constructed to be kept permanently below -18°C by the surrounding permafrost, but climate change and rising temperatures are now threatening its long-term security.

Biorepository sites elsewhere in the world, especially those close to cities, rely on human power sources and are also susceptible to geopolitical upheavals.

Andrew Pask at the University of Melbourne, Australia, who is building a repository for Australian species, is keen on the idea. "We would love to see our samples at duplicate facilities to ensure their safety and, at this point, the moon does seem the safest potential location," he says.

But Rachael Lappan at Monash University in Melbourne says there are many challenges and disadvantages to using the moon, not least accessing it to add or withdraw samples. It may be better to have samples on Earth with a lot of redundancy so that if one repository fails, others are still available, she says.

"I would want to see compelling evidence that we could make use of the [lunar] repository if it was needed," she says.

Even if this facility were never used, Alice Gorman at Flinders University in Adelaide, Australia, sees value in conserving human artefacts in space – perhaps even for any alien civilisations to one day access.

"Repositories, whether they're cryogenically frozen living tissue or DNA, or the entirety of Wikipedia saved on a high-density nickel disc, are going to be just like the Voyager spacecraft golden records," says Gorman, referring to metal discs describing humanity that are attached to these probes, which are now leaving the solar system. ▮

There really is water on the moon

Molecules of water have been detected in lunar rocks for the first time in samples picked up by China's Chang'e 5 spacecraft. These minerals could provide a source of water for a moon base.

The moon was long thought to be bone dry, but in the past 20 years, we have seen signs of water buried below the surface. In 2008, researchers claimed to have found water in volcanic glass beads in samples of lunar rock collected by the Apollo missions. However, that study and others since actually detected hydroxyl groups – oxygen and hydrogen bound together – rather than molecules of H_2O. To get water out of these rocks, they would need to be heated to around 1000°C.

Satellites orbiting the moon have also detected signatures of light that imply the presence of water ice, but this hasn't been directly measured in a sample.

Now, Xiaolong Chen at the Chinese Academy of Sciences in Beijing and his colleagues have analysed around 1000 micrometre-sized grains of lunar soil brought back by Chang'e 5. Using X-ray diffraction, they found a mineral consisting of about 40 per cent H_2O, along with ammonia, magnesium and chlorine (*Nature Astronomy*, doi.org/nbp2). "This is a new form of water stored on the moon," says Chen.

Its chemical structure is similar to that of a mineral called novograblenovite discovered by geologists near a Russian volcano in 2019. This was formed from hot gases from a volcano passing near basalt rock. A similar process may have created the lunar mineral too, says Chen.

The amount of the mineral in the lunar soil was tiny, but it would be easier to extract water from it than from other sources, because it only needs to be heated to about 100°C. Alex Wilkins

Environment

Quantum dots help destroy 'forever chemicals' with light

James Dinneen

SOME hard-to-break-down "forever chemicals" can be destroyed by shining light through nanocrystals.

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) contain carbon-fluorine bonds. These tough bonds make the chemicals useful materials, but have also made them a source of persistent environmental contamination, and some can have damaging health effects. Most methods of destroying the molecules require extreme heat or pressure, or incineration.

Yoichi Kobayashi at Ritsumeikan University in Japan and his colleagues have instead aimed light from an LED at room temperature and pressure at solutions containing either perfluorooctanesulfonate (PFOS), used in firefighting foam and non-stick pans, or Nafion, used in industrial membranes.

Then they added quantum dots, or semiconductor nanocrystals, made of cadmium sulphide and copper. The electrons in quantum dots absorb specific wavelengths of light, which raises them to a more excited state, giving them greater potential to break chemical bonds.

After 8 hours under the LED light, all of the carbon-fluorine bonds in the PFOS broke down. After 24 hours, just over 80 per cent of such bonds were broken in Nafion.

According to the researchers, this breakdown occurs when free electrons from the quantum dots transfer to PFAS near the nanocrystals. The electrons then destroy the carbon-fluorine bond (*Angewandte Chemie International Edition*, doi.org/nbgz).

Michael Wong at Rice University in Texas says the work adds "new twists" to the chemistry of degrading PFAS, but questions remain about how well the method would work with the low concentrations of PFAS found in the environment. ▮

Health

Vision loss and high cholesterol linked to dementia risk

Grace Wade

HIGH cholesterol and vision loss have been identified as two new modifiable risk factors for dementia. Eliminating these factors, along with 12 previously recognised ones, may prevent nearly half of dementia cases worldwide. But genetics and old age still have the greatest influence on a person's chances of developing the condition.

"Dementia might be one of the most important health threats facing the population," says Gill Livingston at University College London. "So, it's incredibly important that there is a possibility that we can change this and have significantly fewer people with [this] illness."

A 2020 review of studies identified 12 potentially modifiable risk factors for dementia: hearing loss, high blood pressure, depression, smoking, heavy alcohol consumption, obesity, air pollution, traumatic brain injury, diabetes, social isolation, physical inactivity and a lack of education.

Livingston and 26 other dementia experts have now updated this list according to the latest evidence and added two risk factors: untreated vision loss later in life and high levels of low-density lipoprotein (LDL) or "bad" cholesterol below the age of 65.

14
modifiable risk factors for dementia have been identified

45%
of cases may be preventable by eliminating these factors

The researchers included high LDL as a factor based on multiple new findings. One was an analysis of 17 studies that followed nearly 1.2 million UK participants younger than 65 for more than a year.

It showed that each 1 millimole per litre increase in levels of LDL was associated with an 8 per cent rise in dementia frequency.

The researchers suggest the association may be due to excess cholesterol in the brain raising the likelihood of stroke, which can cause dementia. Cholesterol has also been linked to an accumulation of plaques of beta-amyloid protein in the brain, which are involved in Alzheimer's disease.

Worsening vision has been linked to dementia

PHILIPPE HUGUEN/AFP VIA GETTY IMAGES

Untreated vision loss was included as a risk factor after an analysis of 14 studies, made up of more than 6.2 million older adults who were cognitively healthy at the start, linked it to a 47 per cent greater risk of developing dementia up to 14.5 years later. "We think that vision [loss] is a risk because it reduces cognitive stimulation," says Livingston. Some research suggests that such stimulation bolsters resilience to dementia.

The researchers used models to estimate that out of all the risk factors, hearing loss and high cholesterol had the greatest impact, each contributing to about 7 per cent of dementia cases, while excess alcohol consumption and obesity had the least influence, each contributing to 1 per cent of cases. Eliminating all factors would prevent an estimated 45 per cent of dementia cases worldwide, they estimated (*The Lancet*, doi.org/nbgx).

However, being associated with dementia doesn't mean these factors cause the condition, says Dylan Williams, also at University College London, who wasn't involved in the report. "Therefore, if we were to target them with interventions, they might not prevent the amount of disease we would expect them to."

The estimates are also averages for the overall population, so don't capture individual risk, he says. This means eliminating the factors from your life may not halve your risk of getting dementia, which is mostly influenced by genetics and age. ▮

Environment

Vaccine could cut cow burp impact

A prototype vaccine reduces climate warming methane emissions from cows by 13 per cent

Madeleine Cuff

A START-UP has developed a vaccine that cuts methane emissions from cow burps, with plans for a commercial launch within three years.

Cattle produce the potent greenhouse gas methane as a byproduct of fermenting grasses and hay in their rumen, the first part of their digestive tract. Agriculture is the biggest source of human-caused methane pollution in the world, largely driven by the burps and farts from the billion cattle farmed globally.

Now, US company ArkeaBio has developed a vaccine to target methane-producing bacteria that live in cows' digestive systems.

Those given the prototype vaccine produced 12.9 per cent less methane over 105 days with no adverse side effects or disruption to growth rate, according to results from a 2023 trial.

The trial was conducted in partnership with Texas A&M AgriLife Research, the agricultural agency of the state of Texas. It involved 10 cows, with five acting as a control group and the other five receiving a vaccination in the neck, followed by a booster shot 56 days later. The results were presented at the American Society of Animal Science annual meeting in Calgary, Canada, in July.

A second trial with 14 cows began in June and is ongoing. Early results suggest a methane reduction of at least 13 per cent per cow, with the effects expected to last beyond three months, says Cliff Lamb at AgriLife.

Cows' digestive systems produce lots of methane, a potent greenhouse gas

STEPHEN DWYER/ALAMY

Methane emissions can already be reduced by changing a cow's diet with feed additives that inhibit the activity of methanogens, the bacteria that produce the methane in a cow's digestive system. But such additives are only useful for farmers who actively feed their cattle, rather than letting them graze on pasture.

Richard Eckard at the University of Melbourne, Australia, says a methane vaccine "is probably the only option that is really going to make an impact" on emissions from grazing cattle.

ArkeaBio's prototype vaccine works by stimulating a cow's immune system to produce antibodies in its saliva, which then target methane-producing microbes in the rumen.

The company aims to bring a vaccine to market that reduces methane emissions by 15 to 20 per cent per cow, sustaining that reduction for at least 3 to 6 months.

"We're comfortable with our mechanism of action," says Colin South at ArkeaBio. "The most important thing to do is show that the mechanism of action works, and then you can take the tools of biotechnology to expand that performance." He predicts a commercial vaccine will be ready in three years and rolled out to millions of cattle within five years.

Alexander Hristov at Pennsylvania State University says ArkeaBio's results seem promising and a 15 to 20 per cent reduction in methane emissions would be substantial, but we need to be sure that it works, delivers consistent results, is economically feasible and has no side effects. ▮

Cosmology

Black holes may inherit magnetic fields from stars

A NEW explanation for how black holes get their extreme magnetic fields could also tell us how the most powerful explosions in the universe are produced.

Gamma ray bursts (GRBs) are intense blasts of radiation generated in cosmic smash-ups. Some of the highest-energy GRBs seem to come from stars exploding in a supernova and producing a fast-spinning black hole.

Physicists think the black hole's spinning weaves its magnetic field into a rope-like structure, which blasts out a jet of matter travelling almost at the speed of light. This then pierces the remains of the parent star and produces a GRB.

But parts of this process were still mysterious, such as how black holes can acquire such a strong and fast-spinning magnetic field from the star that creates them. "When we actually did these calculations, we found that the black holes do not get anywhere close to the magnetic field that we need to launch these relativistic jets," says Ore Gottlieb at Columbia University in New York.

He and his colleagues have now found that if a neutron star – the collapsed core of a massive star – forms for a few seconds before becoming a black hole, this would generate the required magnetic field.

The team ran simulations of a star 40 times the mass of the sun, tracking how its magnetic field changed until the star collapsed and formed a neutron star. The researchers then used a different simulation to track how this magnetic field would change as it became a black hole (arXiv, doi.org/nbpv). "The neutron star is rotating and if its rotation is fast enough, it forms the disc [of material] around the black hole," says Gottlieb. "This is the most important part that was missing in previous simulations."

"If a neutron star forms for a few seconds before becoming a black hole, the magnetic field is boosted"

As well as producing the required magnetic field, extra energy from the neutron star also matches the types of supernovae that are associated with the highest-energy GRBs, he says. ▮

Alex Wilkins

Health

Cognitive effects from severe covid-19 seem to last for years

Michael Le Page

SOME people who were hospitalised with covid-19 in the first wave of the pandemic still have cognitive abilities that are lower than would be expected and there is evidence that this is forcing them to change jobs.

"What we found is that the average cognitive deficit was equivalent to 10 IQ points, based on what would be expected for their age," says Maxime Taquet at the University of Oxford.

His team looked at 475 people in the UK who had been hospitalised with covid-19 and discharged before 31 March 2021. All had completed psychiatric and cognitive assessments six months after their discharge from hospital as part of another study.

Taquet's team asked them to repeat the assessments two to three years later and found that, on average, people's symptoms of depression, anxiety and fatigue had worsened.

"More people are getting worse than getting better," says Taquet.

Overall, 47 per cent had moderate to severe depression at the second assessment compared with 34 per cent at six months, while 40 per cent had moderate to severe fatigue compared with 26 per cent in the first tests.

The proportion of people with moderate to severe anxiety saw a smaller change, rising from 23 to 27 per cent (*Lancet Psychiatry*, doi.org/nbhb).

The results of the cognitive assessments were unchanged, with an average cognitive deficit equivalent to 10 IQ points at both initial and follow-up tests.

As the participants weren't tested before being hospitalised, there is no baseline to compare to, says team member Paul Harrison, also at the University of Oxford.

Instead, the team compared the results to what would be expected for people of the same age, sex and education level, based on a survey called the Great British Intelligence Test.

> "There was a strong association between changing occupation and cognitive decline"

Why so many people's symptoms worsened isn't clear, but the team did find that those with more severe symptoms in the initial psychiatric tests were more likely to see them intensify over time.

Taquet says one participant said it was hard to be short of breath for three years and not experience depression.

The team also found that more than a quarter of participants had changed their occupation since being hospitalised, with half of those saying they did so due to poor health. The researchers found a strong association between changing occupation and cognitive decline, but not with depression, anxiety or fatigue.

This suggests that many people are making the change because they can no longer cope with the cognitive demands of their previous role, rather than because of a lack of energy or interest, says Taquet.

He acknowledges that the study has some major limitations. While around 2500 people were invited to take part in the research, only a fifth responded, so it isn't clear how representative the study is. ▮

Biotechnology

Algae turned into a green fuel 'biofactory'

James Woodford

NEWLY discovered algae have been transformed via selective breeding and genetic engineering to produce fuel in environments that would kill most organisms. The research is a step towards algal "biofactories" that make sustainable fuels.

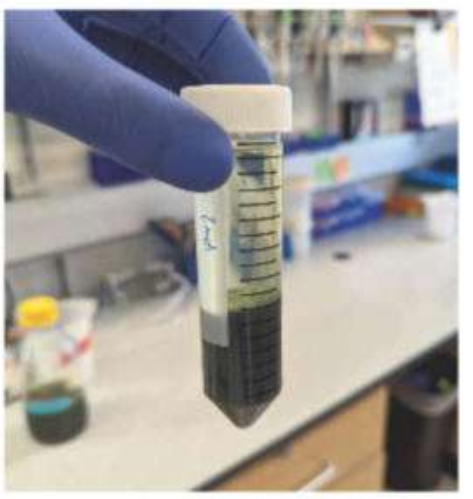
The species, *Chlamydomonas pacifica*, was found in 2020 in a pond at the University of California, San Diego. Now, an engineered strain of it produces oil even when grown in wastewater at temperatures above 40°C (104°F), at a pH higher than 11, in full sunlight and in water half as salty as the ocean. Alkaline conditions keep predators at bay and up the carbon dioxide content of water, which the algae use as a nutrient.

With *C. pacifica*, Stephen Mayfield at the San Diego campus and his team not only discovered a tough species, but one that can reproduce sexually. This meant they could use selective breeding to create a strain with exceptional tolerance of high salinity, light levels and temperatures.

"There is no other extremophile algae that we know of that you can do breeding [with]," says Mayfield.

Like other green algae, *C. pacifica* produces fat to store energy.

Algal biomass grown from *Chlamydomonas pacifica*, a new species



JOÃO VITOR DUTRA MOLINO

However, organisms that live in harsh environments don't usually make good yields of commercially useful products, says Mayfield. "If algae are growing under extreme conditions, their main job is just to stay alive."

To make *C. pacifica* more useful, the researchers inserted genes from soya beans that increase fat production. This increased fat content from 28 per cent of the biomass in the parent strain to 36 per cent in the engineered version (bioRxiv, doi.org/nbg2).

In a separate process, the fats can be converted into biodiesel or polyurethane, a kind of plastic used in waterproof fabrics and many other applications.

36%

Proportion of the algae that is fat, which is used to make biodiesel

Turning to such algae to create oil makes sense. "That's why we have these enormous fossil fuel reserves," says Mayfield, "because for hundreds of millions of years, extremophile algae turned an atmosphere that was 20 per cent carbon dioxide and very low oxygen into an atmosphere that is 20 per cent oxygen today, with CO_2 only a fraction of a per cent. And where did all that CO_2 go? It went into what we know as fossil fuels, ancient algae oil."

Labs elsewhere are making algal strains with similar potential to *C. pacifica*, says Peter Ralph at the University of Technology in Sydney. For this strain, the big test is whether it can be scaled up and survive in larger ponds, he says.

Mayfield says algae similar to *C. pacifica* may one day help us make Mars habitable. There can be an extremophile algae that can terraform Mars, just like one terraformed Earth, he says. ▮

Quantum biology

Brain cells may communicate using quantum entanglement

Karmela Padavic-Callaghan

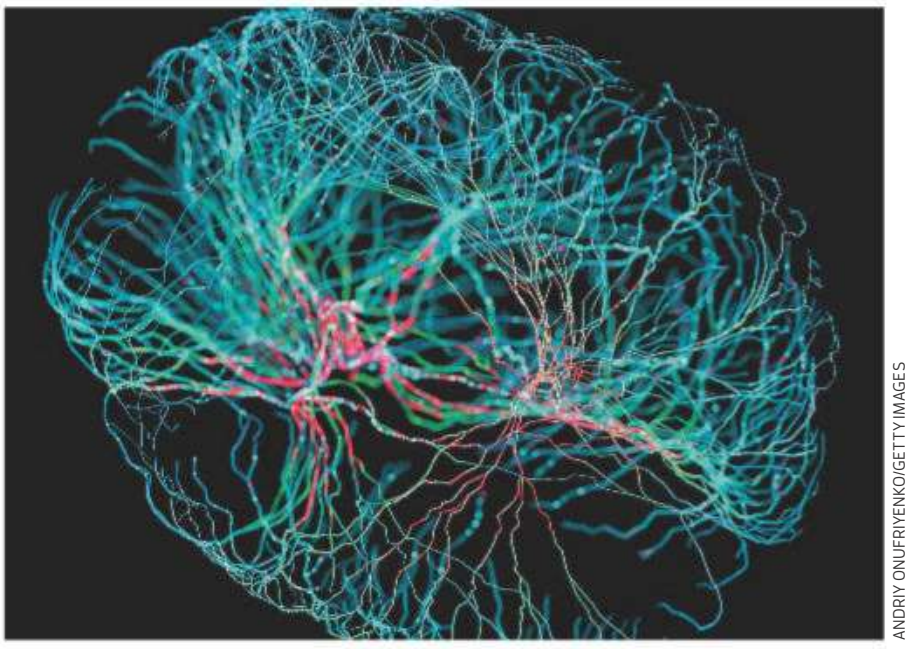
PAIRS of particles linked by quantum entanglement may be produced by the brain's nerve fibres. This phenomenon could explain how millions of cells synchronise their activity to make the brain function.

"When a brain is active, millions of neurons fire simultaneously," says Yong-Cong Chen at Shanghai University in China. Doing so requires even distant cells to coordinate their timing – but what mechanism do they use? "If the power of evolution was looking for handy action over a distance, quantum entanglement would be [an] ideal candidate," he says.

So Chen and his colleagues mathematically investigated one way in which quantum entanglement could originate inside the brain and give rise to the extra-fast communication between neurons.

They focused on the interactions between myelin sheaths – protective coatings of fat molecules surrounding the fibres that connect neurons – and particles of electromagnetic radiation, or photons, produced within the brain. Such radiation hasn't been detected directly, but it has been theorised to originate in neurons' energy-producing mitochondria as part of chemical reactions.

The researchers' calculations showed that, when infrared photons collide with a myelin sheath – modelled as a cylindrical cavity capable of storing and amplifying that electromagnetic radiation – they would impart extra energy to the myelin's chemical bonds. The bonds would then release some of their energy by emitting two photons, one after the other – and many of the pairs would be entangled (*Physical Review E*, in press).



ANDRIY ONUFRIYENKO/GETTY IMAGES

Networks of neurons are weaved together throughout the brain

Once the brain creates entangled photons, the property of entanglement could be passed on to other parts of neurons, like the protein pores that play a role in electrical signalling across the brain, says Chen. When any two objects are quantum entangled, changes in one immediately cause changes in the other – so if different parts of the brain were entangled, they could synchronise faster than through any other type of connection.

Bo Song at the University of Shanghai for Science and Technology and Yousheng Shu at Fudan University, both in China, write in an email that the work "offers a potential source of continuous generation of quantum entanglement in the central nervous system closely related to our cognition".

However, they also say that adding quantum entanglement into brain science "is rather speculative". Both researchers have studied myelin sheaths, including in one experiment where infrared photons were successfully used to affect the neural activity of a mouse.

Finding proof of the theorised entangled photons – for example, directly detecting them in a living system like a mouse – would be hard, says Chen. Instead, he and his colleagues plan to study how entanglement can theoretically affect brain functions. After all, the mere fact that entangled photons could exist in the brain doesn't, by itself, prove that they drive the synchrony of millions of neurons.

"If evolution was looking for action over a distance, quantum entanglement would be ideal"

Until there is more evidence, the role of quantum phenomena in cognition will remain unproven. "Quantum cognition is itself a controversial subject under heavy debates," says Chen. "We won't say there is a direct connection." ▮

Physics

A slight curve helps a rock make the biggest splash

Alex Wilkins

WHEN looking for a rock that will make the biggest possible splash, try searching for one that has a slightly curved surface rather than a flat one. This will produce the largest impact force when it hits water, according to a finding that overturns a long-held belief in physics.

The discovery was made by Jesse Belden at the Naval Undersea Warfare Center in Rhode Island and his colleagues, who set out to examine the idea that a flat object produces the greatest impact on water. To do so, they measured the impact force generated by dropping a half-kilogram aluminium cylinder from different heights into a tank of water about a metre deep. The cylinder was fitted with various shapes of nose cap, ranging from perfectly flat to very curved.

As expected, they found that the perfectly flat nose cap produced a high impact force. "But the surprising piece was that when we gave a slight positive curvature to the nose, extremely slight, that the force was even higher," says Belden.

By using high-speed underwater cameras and complex calculations, the researchers learned that this was down to an air cushion that is produced at the point of impact by various shapes, softening the blow.

Very slightly curved objects produce a thinner cushion than any other shape tested. This tiny variation has an outsized effect: it can increase the force generated on impact with water multiple times compared with a perfectly flat nose or a hemispherical nose (*Physical Review Letters*, doi.org/nbft).

"It's essentially this really subtle difference in the air layer that's on the order of tens of microns," says Belden. The finding could help engineers design boat hulls that minimise the impact force that a vessel experiences, he says. ▮

Technology

An AI is setting speed limits on a US freeway and making illegal suggestions

Matthew Sparkes

DRIVERS on a busy US freeway have been subject to speed limits controlled by an AI since March, as part of a study that has put a machine-learning system in charge of variable limits on the road. The impact on traffic flow and safety is unclear, but the system still sometimes makes suggestions that would break the law.

Roads with variable speed limits, also known as smart motorways, are common in countries including the US, UK and Germany. Normally, rule-based systems monitor the number of vehicles on one of these roads and adjust speeds accordingly. One such road is a 27-kilometre section of the I-24 freeway near Nashville, Tennessee, which was experiencing a problem that besets many busy roads: when there are too many vehicles, phantom traffic jams appear when drivers brake, slowing vehicles to a crawl and risking crashes as fast-moving vehicles come up behind.

To address this, Daniel Work at Vanderbilt University in Nashville and his colleagues trained an AI on historical traffic data to monitor cameras and make decisions on speed limits, deploying it in the I-24 control room in February. Initially, the AI was tested alongside existing software – telling operators what it would have decided – and faced teething problems.

"I think that we're just scratching the surface of a whole new way to operate freeways"

"They look at it and for the first 5 minutes, everybody's like thumbs up, and then they start going to thumbs midway and then it's thumbs down. So hey, it failed in the first 10 minutes," says Work.

After some tweaks, the team launched a new system in March that has been able to operate unaided ever since (arXiv, doi.org/nbcz). The AI works 98 per cent of the time, but will occasionally call for a change in speed limit that is larger than 10 miles per hour, in contravention of federal law.

"It's a bad idea if the measured speed is going 80, 80, 80, 80, 20 – we don't want that," says Work. "We want it to go 70, 60, 50, 40, 30." To ensure this, safeguards switch control back to the old system for the remaining 2 per cent of the time.

It isn't clear how drivers have responded to the system or whether it has improved traffic. The Tennessee Department of Transportation, which manages the I-24 , didn't respond to a request for interview. Work says data on the project won't be released until later this year, as it is still being analysed, but he is positive about the results.

"I think that we're just scratching the surface of a whole new way to operate freeways," says Work. "Anything that we can do to reduce the number of crashes that happen on that roadway, the number of fatalities that happen on that roadway, is worth doing."

Oliver Carsten at the University of Leeds, UK, says that without more data it is impossible to gauge whether the AI is a net benefit or detriment. But he says that some sort of variable speed limit system is key to safety on busy roads.

"There's a well-known limit – 2000 vehicles per lane per hour – at which point you can suddenly go from everything running smoothly at 70 miles an hour to a total breakdown where everything comes almost instantaneously to a total stop," says Carsten. To maintain the traffic movement, you need to bring the maximum speed down, he says. ▮

Plants

New type of wood found in tulip trees soaks up carbon fast

AN ENTIRELY new kind of wood has been discovered, a finding that could turbocharge our ability to use trees to store carbon. Tulip trees have a nanoscale wood structure that sits somewhere between hardwood and softwood, dubbed "midwood".

Jan Łyczakowski at Jagiellonian University in Poland and Raymond Wightman at the University of Cambridge investigated the nanoscale structure of live wood samples taken from 33 species of trees in the botanic garden at the University of Cambridge.

They froze each sample in a nitrogen "slush" that held them at a temperature of -210°C, before studying them using low-temperature scanning electron microscopy. This allowed them to analyse the size of the macrofibrils, tiny rod-like filaments found in the secondary cell walls of wood.

The pair found that hardwood trees, such as oak or birch, have macrofibrils about 15 nanometres in diameter, whereas softwood trees, such as pine or spruce, have larger ones that are 25 nanometres or more in diameter.

But there was a surprising exception, says Łyczakowski. The two species of the *Liriodendron* genus, the tulip tree (*Liriodendron tulipifera*) and the Chinese tulip tree (*Liriodendron chinense*), had macrofibrils around 20 nanometres across, between the two types (*New Phytologist*, doi.org/nbcx).

KATHY GRUBE

A tulip tree in the botanic garden at the University of Cambridge

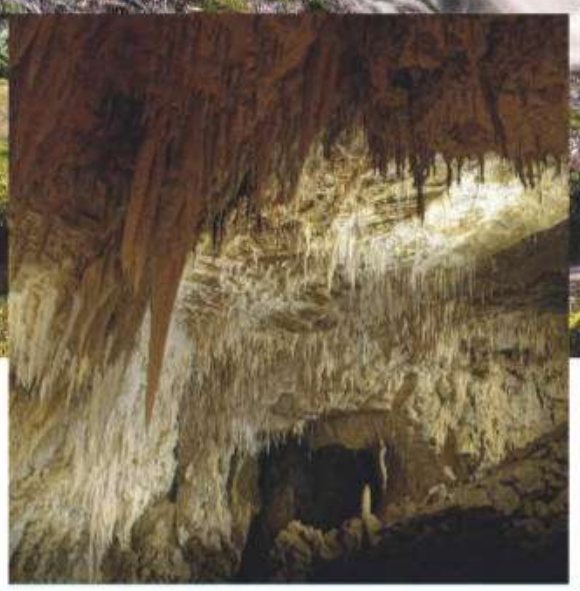
"We knew then there was something special about [these trees]," says Wightman.

Previous work has shown that liriodendrons are fast-growing with high carbon sequestration rates, making them popular candidates for plantations designed to capture carbon.

These trees diverged from their close relative the magnolias some 30 to 50 million years ago. This was a period when atmospheric carbon dioxide concentrations on Earth dropped sharply from 1000 to 320 parts per million.

Their microfibrils may have evolved to make them better at drawing carbon from the atmosphere as concentrations fell, says Łyczakowski. He wants to try to bioengineer trees to have midwood-sized macrofibrils to see if it boosts carbon storage. ▮

Madeleine Cuff



Volcanology, geothermal valleys and astronomy: North Island, New Zealand

1 November 2024 | 8 days

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- Discover Tongariro National Park, New Zealand's oldest national park and a dual UNESCO World Heritage site.

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- Discover two amazing glaciers: Fox and Franz Josef.

Tasmania's flora, fauna and geology: Australia

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Comment

Whipped into shape

After a shocking video of an Olympian whipping a horse, it is time riders educated themselves about the science of horse training, says **Christa Lesté-Lasserre**

DESPITE generally good welfare for horses at the 2024 Paris Olympics, many animal lovers remain haunted by troubling video footage of Britain's triple Olympic gold medallist Charlotte Dujardin mistreating a horse during a training session, which emerged just days before the opening ceremony. Dujardin had been set to compete this summer in dressage – the sport in which horses perform elegant steps and dance-like movements, often to music. But there was a public outcry after the video showed her forcefully striking a clearly distressed horse more than 20 times over a minute-long clip.

Stripped of sponsorships and suspended by the Fédération Equestre Internationale (FEI), Dujardin finds herself under the hot glare of an outraged public – and for good reason. What happened in the video is upsetting and wrong. Those involved in equestrian events need to seize this opportunity to improve horse welfare – as well as the image of the industry – by revamping the way they train horses.

Many equitation scientists, who study the science of horse training, say that, when used correctly, whips offer an acceptable way to extend, or replace, our own arms when gently touching these large animals. It's sort of like using a telescopic pointer on a large screen, says Angelo Telatin at Delaware Valley University.

SIMONE ROTELLA

Dujardin's heavy-handed and senseless use of the whip creates confusion and frustration for the horse, which shows clear signs of psychological stress, says Marc Pierard at the University of Central Lancashire. "You can see that the horse is very tense, and he can't figure out what Charlotte wants. He's getting desperate."

Ethical, science-based training works with contact akin to a tap on the shoulder or a fly on the arm: you touch the horse's leg; it tries different reactions to remove the contact; it finds the "right" way – the one you want it to do – and you remove the contact immediately.

This is rewarding for the horse, but adding a slice of carrot at that precise moment can further strengthen the reward feeling, says Gemma Pearson at The Horse Trust charity. Research shows that well-timed rewards create spikes of dopamine – a feel-good hormone – in the brain. As a result, the horse wants to perform, and is even happy to do so, she says.

Equitation scientists call this concept learning theory, and it has been proven repeatedly in practice. When the rewards come within a second of the horse's action, horses and trainers can enter into a sort of interspecies communication about what they expect of each other. When training is done well, horses soon respond to a simple word, shift in balance or even facial expression.

But learning theory is clearly not what is happening in the Dujardin video, Telatin, Pierard and Pearson agree. Whatever she is trying to teach the horse, she shows no logic in her timing; she adds and removes whip contact randomly regardless of the horse's response. The horse tries a multitude of different responses – but none work. The result: Dujardin hasn't trained the horse in any way.

Critically, though, this incident is a reflection of a sport that is rooted in tradition, rather than science. Dujardin has publicly expressed shame for her actions, but the real problem is a general lack of scientific education about how horses learn – which is sadly common among high-level riders.

This could be a real wake-up call for equestrianism, says Pearson. "It will take a very brave person to step up and say, 'Maybe we need to rethink what we're doing.'" It may need courage, but it is past time for equestrians to get educated about equitation science – to understand how horses learn, and to train them according to that knowledge.

Christa Lesté-Lasserre is a science journalist specialising in animal health and behaviour

Annalee Newitz is a science journalist and author. Their latest book is *Stories Are Weapons: Psychological warfare and the American mind.* They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm reading
The Light Eaters *by Zoë Schlanger, about the complex lives of plants.*

What I'm watching
Weird alternate history series My Lady Jane*, where Lady Jane Grey marries a magical horse.*

What I'm working on
Growing wildflowers in my garden.

This column appears monthly. Up next week: Rowan Hooper

This changes everything

Plant-based internet

Forget videos by gamers or influencers. The best livestream of the year so far was of a corpse flower slowly blooming on an Oregon farm, says **Annalee Newitz**

WHEN you think of livestreaming, if indeed you reflect on it at all, you probably imagine a gamer screaming about shooting the final boss. Or a conspiracy influencer "just asking questions" about why aliens are running Parliament. It is all very loud, with lots of gifs and sound effects. And yet the best livestream so far this year was quite the opposite: it was three weeks of round-the-clock video of a flower slowly growing at Milk Barn Farm, in a town called Boring in Oregon.

This was no ordinary flower. Former web designer Derek Powazek has run the farm for the past decade and is one of the few people on the planet to grow an *Amorphophallus titanum* in his personal greenhouse. Known colloquially as a corpse flower, *A. titanum* produces the world's largest bloom. "I have never smelled a human decaying, but I'm pretty sure it smells like that," Powazek told me by video from his greenhouse, where he was sitting next to the flower he dubbed Fred. "It was a wall of stench."

Normally these plants only grow in the wilds of Sumatra, Indonesia, where they are fertilised by carrion beetles that are drawn to the stink, the way bees are drawn to flowers. Only a few have been cultivated, mostly at universities and fancy botanical gardens.

I started watching the livestream in mid-July, when the flower reached Powazek's waist. It grew several centimetres every day and looked like a slender, green missile wrapped in a massive, purple-edged chard leaf. By skipping backwards and forwards on the livestream, it was easy to see how much it grew in mere hours. I am no stranger to wildlife webcams – I have followed the melodrama of a local peregrine falcon nest for years – but this was something different. Watching a plant grow changed the entire tempo of my day. Instead of focusing on deadlines and minute-by-minute news updates, I slipped into plant time, measured by the slant of light through the greenhouse walls.

Powazek planted his *A. titanum* 13 years ago using a seed given to him by a University of Missouri botanist. Fred sprouted while Powazek was still in a cramped San Francisco apartment and he worried what would happen if it flowered. Where would he put a 1.5-metre-tall flower that reeked of death? Luckily, it rarely blooms, with most growth cycles producing only a single leaf that looks like a small tree.

"I have never smelled a human decaying, but I'm pretty sure the corpse flower smells like that. It was a wall of stench"

In the meantime, Powazek quit his tech job. He and his wife, Heather Champ, moved to Milk Barn Farm, where they learned to rear goats, chickens and turkeys, and grow legal cannabis for CBD oil. Champ still works remotely for a tech firm, while Powazek tends the farm. Fred took up residence in the greenhouse Powazek built for their orchids and other tropical plants.

When Fred bloomed in late July, I watched its leafy wrapper flare open like a skirt, forming what is called a spathe around the missile-shaped spadix. It was as tall as an adult human, and ready to meet the neighbours. Dozens of locals came to admire Fred, some gagging at the smell while others took excited selfies, and hundreds more watched online.

Powazek fertilised Fred on the livestream too, using pollen from another corpse flower with a livestream, at Washington State University in Vancouver, Washington. Biology instructor Dawn Freeman told him to cut a "window" in the thick base of Fred's spathe. Next, he used a tiny paintbrush to reach inside and daub pollen on Fred's female flowers. As he worked, people on Powazek's TikTok begged him not to hurt the plant. "They wanted me to use flies to deliver the pollen – how would I have gotten pollen on the flies?" He smiled. "People got really emotionally involved." Fred took it all quite cheerfully, however, and we got a beautiful view of the tiny pink-and-gold blooms hidden inside.

What is it about extremely slow plant action that we find so emotionally riveting? Powazek thinks it is an escape from a world that feels out of control. "When you're gardening and your hands are dirty, you can't use your phone," he said. "You have to be where you are, giving your love and attention to a thing that is beautiful and isn't going to yell at you on social media."

Still, he did use technology to invite others into his greenhouse. "We forget that social media solves a real problem, which is that we are social creatures and we want to talk to each other. It enabled me to reach out to people and say, 'Look at this cool thing'." Powazek paused and looked up at the deep-green structure towering over his head. "The way we've built social media brings out our worst selves. It turns everyone into advertisers, looking for attention or money. But it doesn't have to be that way."

More and more people seem to agree with him. I would certainly rather watch a giant, stinky plant grow than talk to an AI chatbot. ▮

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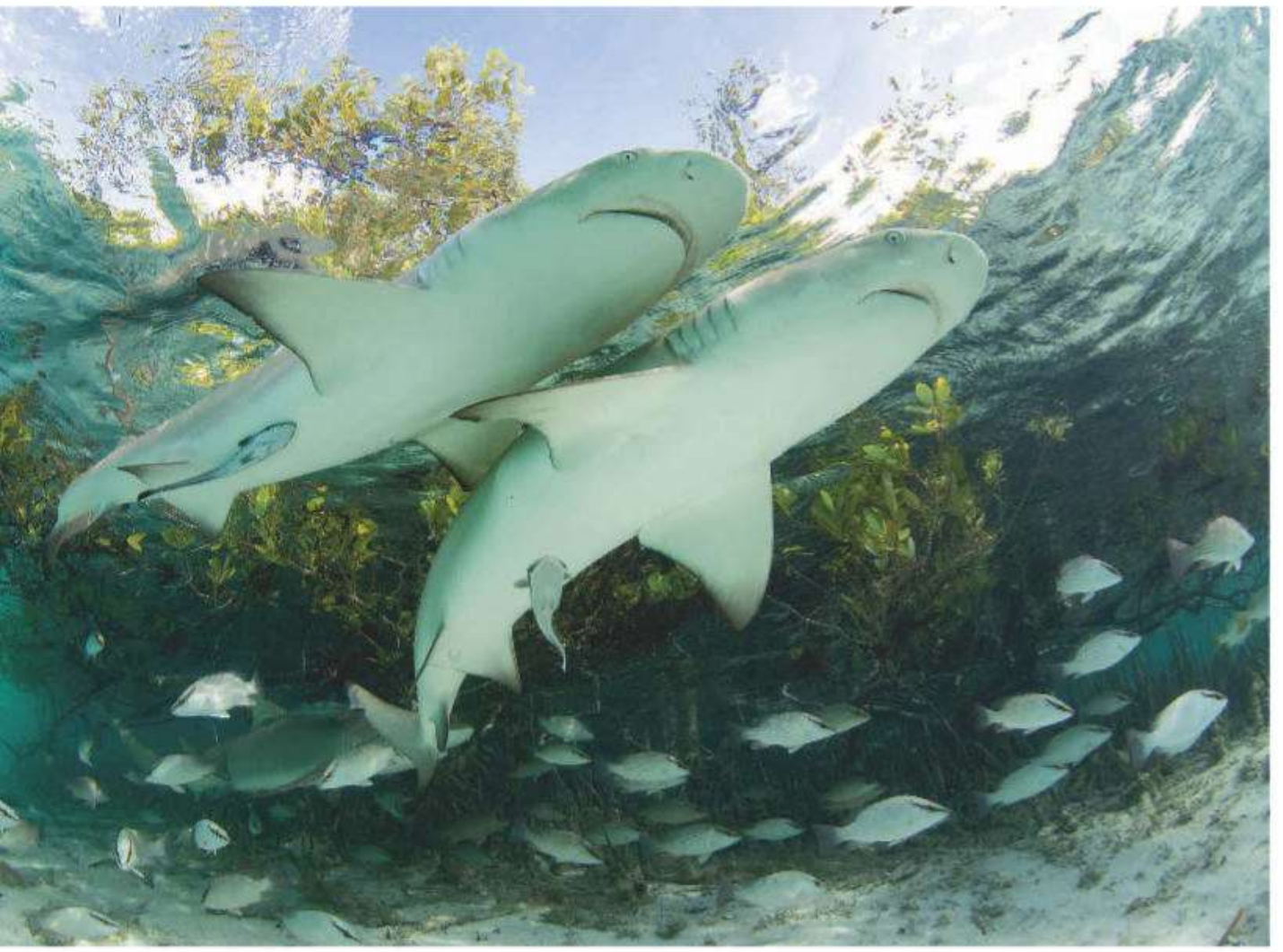


Salty waters

Mangrove Photography Awards
Mangrove Action Project

THESE elegant and serene photos pay homage to a vital yet diminishing ecosystem: mangrove forests. The shots are some of the top entries in this year's Mangrove Photography Awards, telling the story of the beauty, diversity and fragility of mangrove trees, which grow in salty, coastal waters – in stark contrast to most other trees.

Shown at far left is a dramatic photograph of a central strip of mangroves flanking the brilliant blue coast of the United Arab Emirates. Taken by photographer Ammar Alsayed Ahmed, the image was highly commended in the competition's Mangroves & Landscapes category.

The top spot in this category was won by another of Alsayed Ahmed's shots, which shows a gracefully winding river (bottom, near left). The golden clumps of mangrove trees dotted along its length highlight the verdancy these forests bring to the area.

Unfortunately, this isn't the case for an increasing number of mangrove forests worldwide. Despite being biodiversity hotspots and significant carbon stores that help offset climate change, mangroves are under threat from factors like logging, aquaculture and water pollution, in turn threatening the wildlife and people that depend on them.

These include species like lemon sharks, a juvenile pair of which feature in Jillian Morris's entry (top, near left), taken in the Bahamas and highly commended in the Mangroves & Underwater category. Lemon sharks spend the first few years of their lives in mangrove "nurseries" and are one of the many marine species that dwell there.

Gege Li

Partner content paid for by Gilead Sciences

GILEAD

Now is the time for innovation, equity and partnership to end the HIV epidemic

Jared Baeten, MD, PhD
Senior Vice President, Virology
Therapeutic Area Head

Since the beginning of the HIV epidemic in the 1980s, 86 million people globally have been affected by the virus.[1] Many stakeholders across the HIV response continue to prioritize and invest significantly to overcome the epidemic. Cutting-edge science has led to biomedical innovations, transforming HIV into a preventable and treatable chronic condition for millions of people. While tremendous progress has been made, the epidemic persists as one of the most formidable public health challenges.

To end the HIV epidemic, we must go beyond a biomedical approach and fully integrate social determinants of health into the collective response. There is more work to do to achieve the United Nations' (U.N.) goals of ending the epidemic by 2030 (UNAIDS). To achieve these goals, thereby forging a more equitable and innovative HIV response, we must continue to prioritize person-centered HIV research and development and to partner and collaborate for work that is diverse, inclusive and grounded in the voices of communities most affected by HIV.

A new report titled *Going the extra mile to end the HIV epidemic* provides a comprehensive framework for individual countries. The report illuminates how local decision makers can take actionable steps, informed by progress in other regions, and affect real-life impact to help achieve the UNAIDS 2030 goals.

Redefining long-term success in HIV treatment

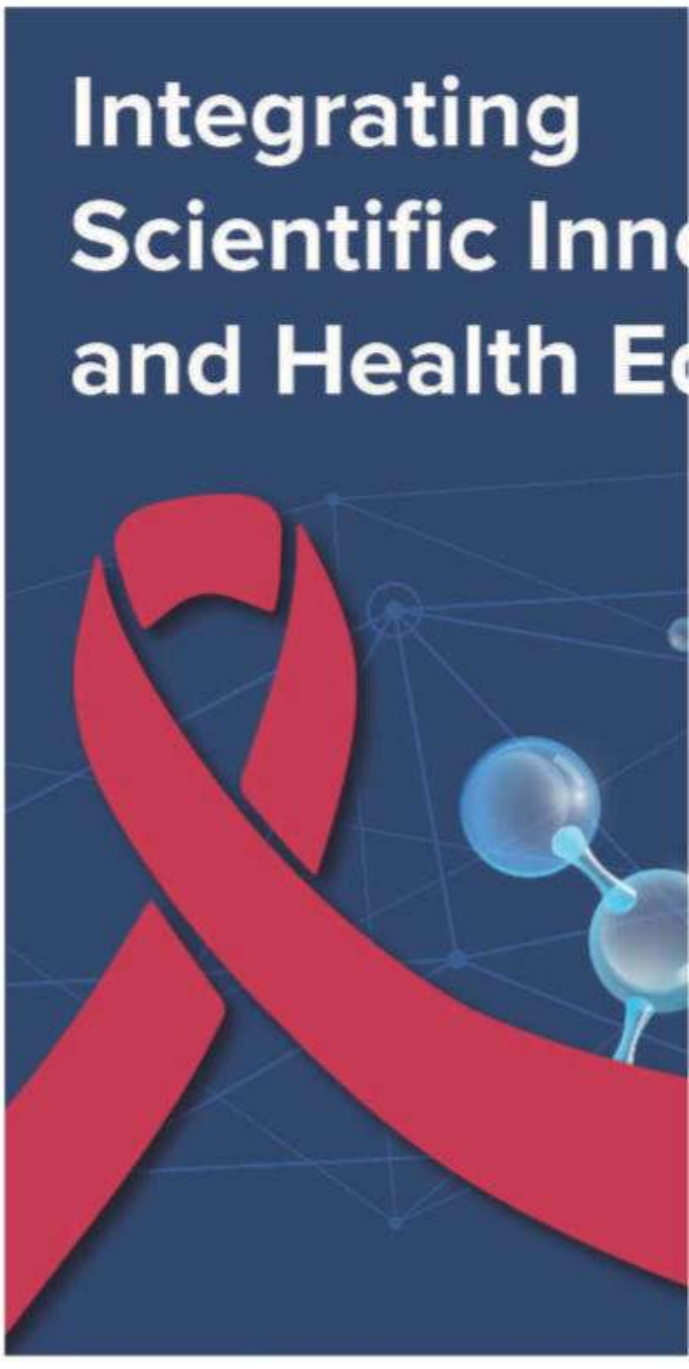
Many strategies are necessary to overcome HIV, and it will be impossible to end the epidemic without bringing HIV treatment to all who need it. The scientific community has made incredible progress with the development of effective HIV treatments that provide virologic suppression, helping people with the virus to lead healthier lives and eliminating the risk of transmitting HIV. At the same time, not everyone is achieving long-term HIV treatment success.

Only two-thirds of people living with HIV globally are virally suppressed.[2] Closing the HIV treatment gap must be a top global priority to eradicate the virus. Long-term success includes selecting the right treatment to prioritize long-term outcomes from the beginning. The HIV treatment landscape is evolving. People are living longer, healthier lives. The increased use of antiretroviral treatment (ART) regimens has been accompanied by the emergence of HIV drug resistance.[3] Long-term HIV treatment and drug resistance remain significant challenges that require diverse, person-centered drug development strategies.

Each person has different day-to-day treatment needs and preferences. There is no "one size fits all" approach. The complexities of HIV care require person-centered innovations that put people at the center of developing new therapies as we keep striving to offer options for all those living with HIV. These evolving needs propel our research teams at Gilead.

One size doesn't fit all – tailoring antiretroviral treatment

Consider the day-to-day realities of three separate people with HIV. One person is retired and has been living with HIV for 30+ years, in addition to heart disease and diabetes. The next is unhoused and is unable to access and safely store their medication. The third is a person of color whose family



has had terrible experiences being mistreated by the healthcare system. They are all living with HIV and need to be virologically suppressed for their entire lives. What each of them needs to achieve successful long-term health outcomes is vastly different. Being able to offer options for a wide range of people requires a holistic approach to care that empowers people affected by HIV to be equal partners in decisions that affect their long-term health and well-being.

Understanding how a person lives and what they are able to do is an essential part of caring for someone affected by HIV. As a collective HIV community, we must look to the future of tailored treatments to meet the needs and preferences of people affected by HIV. This means examining dosing options, such as new single-tablet regimens and combination medications on the horizon. It is about looking closely at the range of administration options available and emphasizing the importance of tailoring those options into the daily lives of those taking the medications.

Advancing health equity

The HIV epidemic is fueled by racial, gender, class and sexual discrimination at the community and systemic levels. These inequities must be addressed to end the epidemic. Ensuring that all people affected by the virus have equitable access to the quality care they need and deserve, particularly those disproportionately affected by other health inequities, is at the forefront of the HIV community's efforts.

Achieving health equity requires partnership with governments , scientists, clinicians and community. It will continue to take togetherness to reduce disparities, advance education among healthcare professionals and support the local communities in which they operate. We work closely with partners and grassroots organizations to address deep-rooted barriers to access — like stigma — to reach underrepresented and disproportionately affected communities, including Black, Latine, LGBTQ+ and aging individuals.

Bringing community voices into the research process is another way to advance health equity. From planning to execution, while looking at real-world and participant-reported outcomes, they have direct line of sight into how treatments work. For example, our team is spearheading additional innovative programs which include communities that have been historically underrepresented in HIV clinical research such as members of the LGBTQ+ community, women, young people and people of color. It is paramount that our research (Gilead, is directly informed by the diverse voices of people affected by HIV and the advocates and communities that surround them during every step of our development process.

Going the extra mile to end the HIV epidemic

The response to the HIV epidemic is at a crossroads. We cannot break the trajectory of this epidemic unless people and communities are at the center of the collective response.

To further reduce stigma, improve healthcare access and quality, and enhance local leadership and advocacy, we require more than medicine – we need ongoing and substantial community investment.

Gilead recognizes the need for innovative approaches to address the diverse needs of individuals and communities affected by HIV. Our dedication to transformational innovation extends beyond the laboratory. We believe in collaborating at the global, national, and local levels to bridge gaps in HIV awareness and improve linkage to and retention in care.

References: 1. World Health Organization, Summary of the global HIV epidemic, 2022 (https://www.who.int/data/gho/data/themes/hiv-aids) 2. World Health Organization, HIV and AIDS, 2023 (https://www.who.int/news-room/fact-sheets/detail/hiv-aids) 3. World Health Organization, HIV and drug resistance, 2024 (https://www.who.int/news-room/fact-sheets/detail/hiv-drug-resistance)

All life is here

The complex dynamic of how life has shaped Earth delivers an excellent finale to an ambitious trilogy exploring the evolution of intelligence, says **Elle Hunt**

Book

Living On Earth

Peter Godfrey-Smith

William Collins (UK, out now); Farrar, Straus and Giroux, (US, 3 September)

IN 2016, Peter Godfrey-Smith landed an unexpected bestseller with *Other Minds*: *The octopus and the evolution of intelligent life*. It was widely acclaimed for its insight into the consciousness of a relatively alien life form, lent colour and character by Godfrey-Smith's regular encounters with cephalopods off the beaches of his Sydney home – which explains why he is often billed as the "scuba-diving philosopher".

In the 2020 follow-up, *Metazoa: Animal minds and the birth of consciousness,* the author expanded his scope to all animal sentience, setting out how beings as different as humans, insects and corals might experience life on our shared planet. *Living On Earth* concludes the trilogy and is even more ambitious, joining the dots between "life, consciousness and the making of the natural world", according to its subtitle.

The story begins long before *Homo sapiens*, with cyanobacteria, the tiny, oxygen-producing microorganisms that, about 3 billion years ago, created the conditions for complex life. From here, Godfrey-Smith charts the evolution of plants and animals, showing how each break from the "tree of life" reflects the changing environment and eventually also shapes it.

His aim, he writes, is to tell the "history of how life has changed the Earth", unpicking the dynamic cause-and-effect relationship between plants and animals and their environment. It is a mammoth undertaking, but he approaches it like the proverb about how to eat an elephant: one bite at a time. To say he writes clearly sounds like faint praise, but on such an unwieldy subject, it is no mean feat.

In *Living On Earth*, Godfrey-Smith presents himself as a patient guide, leading you step by step through vastly different time periods and terrains. His clear signposting of how separate paths of history converge, and where certain expert views and the published science differ, further encourages confidence. Recognising the foolhardiness (if not futility) of trying to be an omnipotent expert, he is transparent not only about his sources but also where his own mind is not yet made up.

"All life on Earth is a product of 'patterns of action' such as building and learned behaviours"

The effect is engaging, positioning the reader over Godfrey-Smith's shoulder, watching him think. But you would be forgiven for needing the occasional time-out. Though sensibly structured into short sections, *Living On Earth* is unavoidably dense and occasionally abstract, as the author himself acknowledges.

Where *Other Minds* had a central character in the octopus, *Living On Earth* supplements the main thread of evolution with examples and vignettes. These breathe life into the narrative, giving readers a chance to take stock of the necessarily brisk tour through ancient history while also showing the results of the processes he describes.

Many of Godfrey-Smith's case studies are drawn from his home country, Australia, which holds fossil evidence of the times many animal groups split from their forebears, as well as examples of their "living representatives". His observations of the birds, reptiles and other wildlife that visit his backyard serves to illustrate the role of certain animal behaviours and activities – for instance, birds' songs and mating displays – and how they might have come to be.

These vignettes not only aid our understanding of Godfrey Smith's grand tour but also show that the processes of adaptation and transformation he describes are ongoing. Plus, in today's Anthropocene age, they are driven by human activity.

The final third of the book tackles farming, animal experiments and the threats posed by climate change and habitat loss, using a "kind of ecological outlook" so we can see the big picture and our place in it.

To a greater or lesser extent, Godfrey-Smith argues, all life on Earth is a product of "patterns of action" such as building and other learned behaviours. In this clever, compassionate and often deeply moving book, he encourages us to consider not just how we got here, but where we choose to go next. ▮

Elle Hunt is a writer based in Norfolk, UK

Australia's red-winged parrot feeding in fields in the Northern Territory

ROLAND SEITRE/NATUREPL.COM

The tale of a tree

Gentle, intimate cinematography plus a "cast" of real animals deliver an ode to an oak, finds **Katie Smith-Wong**

Film

Heart of an Oak
Laurent Charbonnier and Michel Seydoux
Icon Film Channel; selected UK cinemas

ICON FILM DISTRIBUTION

THE oak tree is more than just a tree. For centuries, it has been seen as a symbol of fertility and resilience. In the UK, these trees provide food and shelter to more than 2300 species, of which 326 rely on them for survival.

Oak trees can live for more than a millennium, but 600 years is more typical, and they acquire "ancient" status at 400 and "veteran" status between 150 and 300. This longevity means they support more species and stable populations over time, making them an essential part of biodiversity – something directors Laurent Charbonnier and Michel Seydoux highlight in their nature documentary *Heart of an Oak*.

Spanning 12 months in the life of a 210-year-old pedunculate oak in Sologne, Centre-Val de Loire, France, the film captures the natural world in various states. Alongside the lone woodland tree, a family of wood mice, a couple of Eurasian jays and a red squirrel are among the film's stars, as they hunt or forage and occasionally hide from other "residents" just to survive.

***Heart of an Oak* offers few embellishments: there is a minimal score and no narration. In their place is an emphasis on animal calls and actions, and even differences in the sound of leaves rustling as the seasons swiftly change on screen. This produces an overall peace and general stillness in which audiences can take refuge as they enjoy the simplicity and beauty of nature.**

Seydoux and Charbonnier do, however, allow occasional musical interludes. For instance, Dean Martin's song *Sway* accompanies a romantic interlude between two acorn weevils. And a tense scene where an Aesculapian snake slowly approaches two chirping chicks, eliciting panicked squawks from nearby birds, features a chilling percussive track. Sparingly used, these moments help bring a different tone to the documentary, while reminding audiences that nature isn't completely peaceful and friendly.

Heart of an Oak follows this 210-year-old tree and its inhabitants through the seasons

Overall, the film offers an emotional investment that extends beyond the oak. From behind the camera, the directors carefully build rapport with the animals so audiences can empathise with their seeming joy or fear. This is mostly down to the ambience of the film, created by cinematographer Mathieu Giombini. The consistently detailed and intimate visuals offer a window into the world of each species, showing their individual behaviours, whether that is scurrying for food or cowering in fear from an impending downpour.

This style is perfectly complemented by Sylvie Lager's smart editing, so sequences such as an imminent threat from a badger to a lone wood mouse during its routine hunt for acorns become exciting. An even more telling example of this editing is a thrilling chase between a Eurasian goshawk and a Eurasian jay, highlighting spectacular aerial photography and creating a sense of danger that disrupts what is otherwise often a serene environment.

While animals dominate above ground, several animated sequences provide an educational glimpse into the circle of life under the surface. Sporadic interludes show the roots of trees creating a supportive "neural network" with surrounding trees. In parallel, a lone acorn planted by a squirrel begins a new life as a sapling – an indicator of a future means of survival.

Quietly understated in its lucidity and grace, *Heart of an Oak* combines lush and vibrant cinematography with gentle direction to deliver an enthralling celebration of the natural world.

Katie Smith-Wong is a film critic based in London

New Scientist *recommends*

Chelsea Whyte
US editor
New York

If you enjoyed the 1996 action rom-com *Twister*, you'll like the sequel. At least, I did. The pluralised **Twisters** picks up 30 years later, and the plot is broadly the same, but with more tornadoes, reflecting the reality of today's extreme weather.

We follow two rival groups of storm chasers, although this time the merry band of weirdos is billed as "the other guys", while the government-funded, high-tech troupe is where we find our hero, Kate Cooper (Daisy Edgar-Jones, pictured).

Cooper is a young meteorologist haunted by a traumatic past. She has an almost absurd ability to predict the path of an erratic tornado. So much so, I scoffed a bit.

Her mission is to stop twisters forming, using cloud seeding, moisture-absorbing chemicals and the like. All very science-inspired – except for the scale of the effects, which is just silly. But I don't go to summer movies for the science: wild effects, a cheesy love story and hilarious moments are entertaining enough to sweep me along for a few hours.

UNIVERSAL PICTURES, WARNER BROS. PICTURES & AMBLIN ENTERTAINMENT

The TV column

Fun and games Netflix's *The Decameron* adds style and literary tropes to a licentious 14th-century classic. But it keeps the original's attacks on class and power, adding veiled satire about our own tech elite, says Bethan Ackerley

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on X @inkerley

GIULIA PARMIGIANI/NETFLIX

What to do when plague calls? Retreat to a country mansion and party

THE influential thinker and writer Douglas Rushkoff was once summoned to an audience with five Silicon Valley billionaires. As he recounts in *Survival of the Richest*, their concern was impending apocalypse – not how they might prevent it, but how to outrun it. The preppers quizzed Rushkoff on threats to humanity and where to build their bunkers. But most crucial was how they could stop their hired security, required to deal with angry mobs storming the proverbial gates, from wresting control of the refuges the moguls had built.

That last question is of utmost importance in *The Decameron*, a bawdy, eight-part adaptation of writer Giovanni Boccaccio's collection of short stories. In the 14th-century original, 10 young people shelter in a villa outside Florence, Italy, to escape the Black Death. To pass the time, they tell tales of love and licentiousness. In Netflix's very loose take, what starts as a bacchanal descends into a fight for survival, especially as the rigid class boundaries unravel.

Arriving at the idyllic Villa Santa, Florentine society A-listers are welcomed by Sirisco (Tony Hale), steward to the absent Visconte Leonardo. Chief among the guests is Pampinea (Zosia Mamet), a spoiled socialite who bullies her underling Misia (Saoirse-Monica Jackson) and is soon to be married to Leonardo.

As the revellers (and servants) pile in, their secrets are revealed: Filomena (Tanya Reynolds) is in fact Licisca, her long-suffering lackey. Misia is harbouring her lover in the cellars, while the pious Neifile (Lou Gala) and her wily husband Panfilo (Karan Gill) both lust after physician Dioneo (Amar Chadha-Patel). Far from Florence's pustulated underbelly, they are free to seduce and outdo each other – until the outside world comes knocking.

"What starts as a bacchanal descends into a fight for survival, especially when class boundaries unravel"

There is a healthy amount of Monty Pythonesque silliness throughout, alongside tropes from early modern literature. Expect mistaken identities, shrewd servants, foolish nobles and gender politics. The anachronisms are well chosen: the cast use their own accents and their antics are set to music from the likes of Depeche Mode and New Order. Add fine comedic chops – Hale and Jackson are excellent, as is Jessica Plummer (the real Filomena) – and there is a lot to love.

It is also refreshing that *The Decameron* burns through its storylines fast. Events you may imagine playing out in the season finale sneak up and are replaced with more intrigue, largely successfully. The jumble of plots that unfold – some erotic, some tragic, some just fun – retains some of the original's rich storytelling. But we always return to the power struggle.

So while this *Decameron* works well as ribald Renaissance farce, its steelier class commentary is also, however indirectly, an excellent satire on our tech elite preppers. Through wealth and power, the Villa Santa nobles want to buy survival, but are stumped when it comes to their servants. They can't live without them, but can't control them either, not when the crisis raging outside has made the old order irrelevant.

Whether by colonising Mars or hiding in remote compounds, the Musks and Zuckerbergs of our time are dreaming up their own Villa Santas. As Rushkoff puts it, they are indulging fantasies of escaping from the rest of us. *The Decameron* is a lesson in how such sanctuaries may or may not change hands – and it is hilarious to boot. ▮

TV

The Decameron
Kathleen Jordan
Netflix

Bethan also recommends...

TV

Arrested Development
Mitchell Hurwitz
Netflix
Tony Hale, who plays Sirisco in The Decameron*, made his name as Buster Bluth in this cult sitcom about a wealthy and dysfunctional family. Possibly the cleverest comedy ever made.*

Derry Girls
Lisa McGee
Netflix
*Saoirse-Monica Jackson (*The Decameron*'s Misia) has the most expressive face on TV. She plays Erin, a teenager in Northern Ireland during the Troubles – it is far funnier than that sounds.*

Editor's pick

Digital primordial life has a message for us

13 July, p 8

From Dan Roberts, Beach Park, Illinois, US

You report that self-replicating virtual life forms have been found to emerge "from a digital primordial soup", an example of order arising in seemingly unlikely circumstances. Is it possible we have overlooked something fundamental about the universe? Have we failed to create a theory to explain the existence of order, which seems to emerge wherever there is available energy?

From the structures of subatomic particles to those of galactic superclusters, order is evident in the universe. Ever since the earliest moments in time, when the cosmic microwave background revealed its patterns, up to the present day, orderly structures are the norm.

Given the ubiquity of the evidence for the development of order from chaos, it seems likely to me that there is a corollary to the laws of thermodynamics governing this process.

From Julian Cowans, St Ives, Cornwall, UK

That self-replicating virtual life emerged from random data surely increases the probability that we are living in a simulation, the possibility of which was raised by philosopher Nick Bostrom. One of the key notions connected to this, he suggested, would be the existence of posthumans capable of running simulations of evolutionary history. It now turns out this could be far easier to do than previously imagined.

Look to the oceans for LUCA's birthplace

20 July, p 9

From Garry Marley, Stillwater, Oklahoma, US

You report evidence of an earlier origin of LUCA (the last universal common ancestor of all life), around 4.2 billion years ago. If LUCA emerged then, this would give just a 300-million-year window between the formation of Earth's surface and life's origin.

It seems unlikely this could have occurred on the hot, primordial surface. A less disruptive location would be ocean hydrothermal vents, where chemosynthesis – in which carbohydrate is made in the absence of light – takes place.

Overcoming the fear of exercise is really hard

27 July, p 38

From Dave Wilson, Leeds, UK

Your article on psychological barriers to exercise only addressed one aspect of the issue. I doubt I am alone in associating exercise with fear, even when someone else is doing it. I had to take my courage in both hands to read all your articles on exercise, and by the end I had definite signs of anxiety: racing pulse, grinding teeth, fist clenched as if fighting pain.

I have pushed through such feelings and taken up exercise routines in the past, sometimes for months. The fear never reduced, it just became part of the process. People don't like to admit fear. It is easier to claim a lack of motivation. I suspect a lot of psychological barriers to exercise aren't about the absence of a positive, but the presence of a negative.

More ways to store renewable energy

20 July, p 36

From Tony Castaldo, San Antonio, Texas, US

Gravitricity's energy-storage scheme uses a 25-tonne weight dangled in an old mine. Since a great deal of wind energy is generated offshore, we could use excess electricity to pull a large air-filled float down to the sea floor and, in times of need, use its rise to generate electricity.

To displace 25 tonnes of water, we would need a 25-cubic-metre float – a sphere with a radius of less than 2 metres. We might want a much larger one, of course.

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Roger Harrabin speaks of massive energy-storage projects involving weights in deep mines, but it occurred to me that all new-build houses could include some sort of double wall with an individual "falling weight" device, wound up by the output of solar panels or wind generators during daytime and allowed to gradually fall in the night, generating light and heat.

Did these more ancient Americans arrive by sea?

27 July, p 18

From Bruce Denness, Niton, Isle of Wight, UK

Evidence of human occupation in South America now dates back as far as 21,000 years. If correct, this would predate the currently accepted arrival of people in the Americas by at least 1000 years. It would also support my suggestion (Letters, 2 May 2020) that the Americas were first occupied by Polynesian people escaping from atolls that were inundated by rapidly rising sea levels, rather than via a land bridge between north-east Asia and North America.

How we keep aircraft safer far from land

20 July, p 14

From Peter Brooker, London, UK

Aviation safety over oceans isn't solely dependent on navigational systems like GPS, which, as you report, have been subject to jamming. Aircraft carry a traffic alert and collision avoidance set-up, an independent radar-based system, to reduce collision risk. It works well for aircraft in the usual flight/cruise conditions, assuming the crew pay attention to alerts and advisories.

Latest fusion delay is a real let down

6 July, p 13

From Andrew Hawkins, Peaslake, Surrey, UK

At the age of 78, it was very disappointing to read that the ITER fusion reactor project in France is apparently not going to be fired up in my lifetime, if ever.

Life choices have kept my ageing brain sharp

20 July, p 32

From Pamela Ross, Findochty, Moray, UK

The idea that middle-age lifestyle choices can influence how your brain ages is interesting. When I was 42, my husband died, leaving me with four children and debt. I went back to college, retrained for a different career, took my driving test, remortgaged and got on with life. I got a job, joined a union and did a degree with the Open University (I started reading *New Scientist* then – a good result!).

A few years ago, when I was almost 70, I left my home of 30 years and moved more than 600 kilometres away to live in a place where I knew nobody. I think you need to give yourself challenges in life to keep alert and fresh. I am sure this has positive outcomes for brain health.

For the record

Typical simulations of the universe assume gas extends by 10 to 20 per cent outside a galaxy's outer limit (27 July, p 10).

Want to get in touch?

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MICHAEL KIRKHAM

The one and only

The stereotype is that only children are spoilt, self-centred and neurotic. Now, researchers are turning some of these common misconceptions on their head, finds **Amanda Ruggeri**

I AM an only child. Saying this sometimes feels like a confession – not least when people respond with a well-meaning "oh, you don't seem like it!". Now, as the mother of a preschooler, I see my daughter navigating the same assumptions. "Does she have older siblings?" one teacher asked recently. "She plays so well with the other kids!"

If it seems like I am bragging about my (or my daughter's) behaviour, you will have to excuse me: I am, after all, an only child.

For over a century, we have been seen as odd, at best; antisocial, neurotic and narcissistic, at worst. "Being an only child is a disease in itself," declared 19th-century child psychologist Granville Stanley Hall.

Whether there are actually any differences between the personalities and well-being of singleton children and those with siblings remains a contentious question – one given fresh impetus by the growing trend of one-and-done parenting.

Single-child families have become more common since the 1970s in high-income countries, including the US and UK, whether "by constraint or by choice", says Éva Beaujouan, a demographer at the University of Vienna, Austria. In Europe, nearly half of all households with children have just one child.

Despite their growing popularity, one-child families continue to encounter a long-held view that this arrangement is somehow harmful. Fortunately, delving into contemporary research can offer a degree of clarity – and it hints that being an only child can come with surprising outcomes. The findings may offer some reassurance for one-and-done parents and those still debating how many children to have.

The negative stereotype of only children is often said to date back to Hall, the first president of the American Psychological Association in 1892. But it was his protégé, E. W. Bohannon, who gave Hall's beliefs the gloss of science by conducting one of the first studies on the subject. In it, Bohannon characterised more than 1000 children he considered to be "peculiar and exceptional", categorising them by traits as varied (and dubious) as "stout", "obedient" and "whining". Being an only child, which applied to just 46 of the children – and which, he claimed, was marked by characteristics like "selfishness" – received a category of its own.

It is likely, though, that only children were viewed as the odd ones out far earlier than this. That is because, statistically, they would have been. While it is easy to forget now, women arguably have been able to control their fertility in a dependable way only since the 1960s, with the advent of the contraceptive pill. Our hunter-gatherer ancestors averaged around four or five live births in a lifetime, while the settled lifestyles and more predictable nutrition of the agricultural revolution led families to have even more children, more quickly.

Damning stereotypes

The upshot was that, for almost all of human history, only children often signified some kind of family issue, like poor parental health or malnutrition, says Toni Falbo at the University of Texas at Austin, a leading researcher of only children.

The relative unlikelihood of being an only child in the past has probably led to the assumptions of our weirdness. After all, it is human nature to ascribe one notable characteristic to another notable characteristic, says psychologist Michael Dufner at Witten/Herdecke University in Germany. "People often look for the attribute that distinguishes you from the others, and use that to explain how you behave," he says. If an only child doesn't share, onlookers may be quick to say it is because they are an only child. But if a child with siblings doesn't share, few would attribute it to their having siblings.

This has caused the entrenchment of some particularly damning stereotypes. A 2019 study by Dufner that compared the narcissistic tendencies of 1810 adults who did and didn't have siblings is a case in point. The researchers also polled a further 556 people about the type of person they thought likely to be narcissistic.

Contrary to the ingrained belief, adults without siblings were no more likely to show narcissistic tendencies than those who did have siblings. Unfortunately, the study also showed that respondents had bought into the stereotype. They were far more likely to say that only children were narcissistic – especially if they had siblings themselves.

"If you're not an only child, then you tend to think that these only children are all spoiled narcissists," says Dufner. "But it seems not to be true."

Such bias hasn't just moulded cultural perceptions. It has shaped decades of research – a wrong turn made worse by other methodological issues, like small sample sizes and a failure to control for other factors that could explain any differences. To get closer to the truth, we need to look to better-designed studies of only children and see what they say. Doing so reveals a very different picture, even if it is sometimes still blurry. "Both ›

educationally and developmentally, [only children] tend to either be better off, or show no difference at all," says Katherine Keenan, a demographer and population geographer at the University of St Andrews, UK.

One popular misconception that has been debunked by rigorous study is the oft-claimed view that lone offspring end up with poorer well-being than their counterparts. Research that surveyed 3221 US adults as 29-year-olds and contrasted their responses with those from when they were in high school in 1960, for example, found that only children were either equally happy and satisfied with their lives – or more so – than those with siblings.

More recent research has come to similar findings. In May, a meta-analysis of 113 studies that included almost 240,000 participants in China led by Yu Tao Xiang at the University of Macau, China, concluded that only children were less likely to show a variety of mental health conditions, including depression, anxiety and OCD, than those with siblings.

Not having siblings means you also tend to do a little better on IQ tests and in school, presumably because parents have more time and resources to talk to and interact with just one child. In the long term, though, these educational differences may even out.

The lonely only-child trope is crumbling too. In 2022, Shengjie Lin, then at the University of Texas at Austin, and his colleagues looked at more than 1200 young adults in China and found that only children reported being less lonely than those with siblings.

"The evidence is not there," says Falbo. "Some of the research for late childhood and early adolescence suggests that only children do spend more time on their own. But they're not distressed by this."

While the lack of correlation between "only" and "lonely" might surprise those with siblings, it tracks with what we now know about loneliness. It is a complex phenomenon, and more related to the quality, not number, of relationships someone has – not only for adults, but children and adolescents.

Power of one

That applies as much to your siblings, should you have them, as to other relationships. One 2009 review noted that while having a good sibling relationship can have benefits, a poor one was linked to everything from worse academic outcomes to aggression. More surprisingly, it reported links between positive sibling relationships and later problem behaviour, if one of the siblings engaged in "deviant behaviour" like substance use or school delinquency.

Having a large number of siblings can also be problematic. Last year, Douglas Downey and Rui Cao at the Ohio State University published work on some 18,000 teenagers across the US and China that concluded having more siblings was linked with poorer mental health. And this year, a study by Keenan and her colleagues discovered that having three or more siblings came with a higher risk of both cancer and worse overall health at midlife. "The record is pretty clear," says Falbo.

It is a similar story when it comes to the idea of the selfish only child. The reverse may actually be true. In one of her earliest studies, Falbo used a prisoner's dilemma game, which permits the use of cooperative or competitive behaviour, to see how children interacted. Rather than being more competitive than kids with siblings, only children were the most likely to respond to a cooperative move in kind. This suggests, she wrote, that "growing up with siblings enhances interpersonal competitiveness rather than cooperativeness".

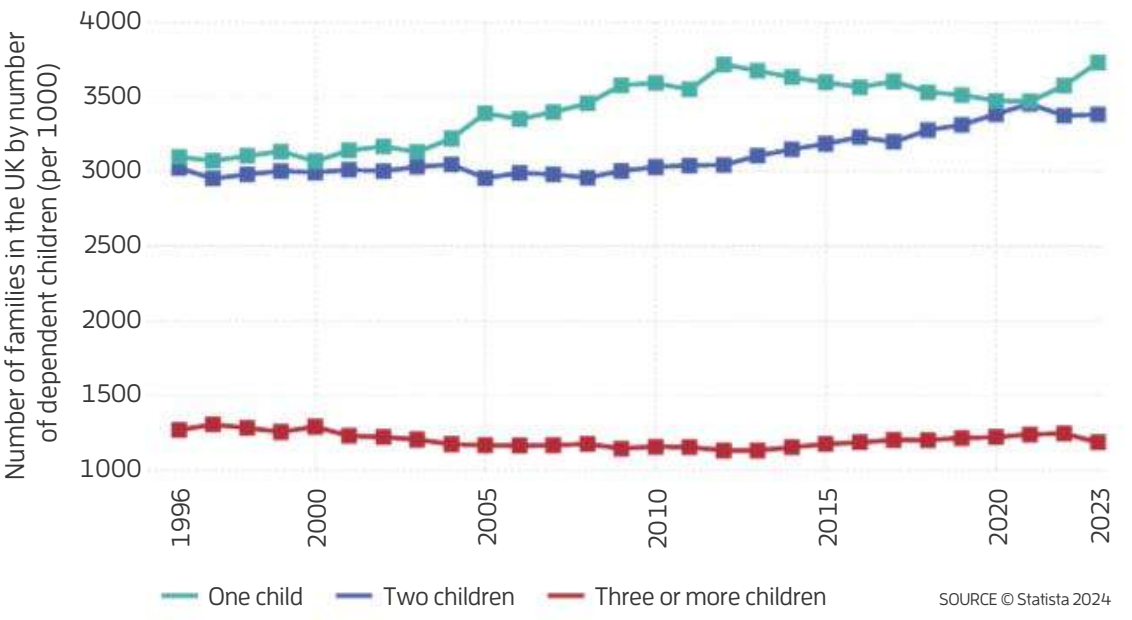
Still, she doesn't dismiss the idea that children without siblings may be a little different in terms of sociability – if, by this, we mean being more comfortable on their own.

That could even play into one long-term finding of a potential difference that does seem to hold water: only children are slightly more likely to divorce than those with siblings. In one sample examined to reach that

D3SIGN/GETTY IMAGES

Only children on the rise

One-child families have become more common in high-income countries, including the US, UK and in the European Union. In the UK, the number of one-child families has increased by a fifth since 1996, while the number of families with three or more children has slightly decreased.



Studies have found that only children are just as happy and satisfied with their lives as children with siblings

conclusion, each sibling someone had reduced their divorce risk by about 3 per cent. The researchers suggest that this stems from a difference in interpersonal skills. Falbo isn't so sure. She thinks only children may simply be more comfortable striking out on their own.

Meanwhile, even researchers who have argued that having brothers and sisters provides an advantage in social skills say the scale of the difference is often overblown.

One of the most-cited pieces of work that supports the social skills divide is a 2004 look at more than 20,000 5 and 6-year-olds in kindergarten in the US. As rated by their teachers, only children were found to have more trouble with interpersonal skills, self-control and problem behaviours like interrupting or fighting. Even five years later, according to a follow-up study in 2015, only children hadn't caught up on this front.

Little difference

However, any differences were minor. When you drill down into various aspects of social skills, the largest gap concerned interpersonal skills: in kindergarten, the average rating for this was 3.04 out of 4 for only children versus 3.15 out of 4 for kids with siblings. By fifth grade, it narrowed to 3.12 for only children and 3.18 for siblings. "The difference is not meaningful," says Deniz Yucel, a sociologist at William Paterson University in New Jersey and a co-author of the 2015 follow-up study. More confusingly still, some research has found the opposite: that only children are more social and better liked than their peers.

And of course social skills lend themselves to forming close friendships. Is this easier if you have had to get along with siblings? Yucel co-authored a study in 2015 on this, finding that, in general, kids with siblings were no more likely to have such friendships than only children. However, they were a little more likely to if their sibling relationships were high quality.

It could be that these children had learned social skills from their siblings. Or, wrote Yucel, it could be a chicken-and-egg conundrum: a more sociable child simply has better relationships with both siblings and peers.

Which brings us to the kind of quandary that can muddy these waters, despite all the research. It is the question of how environmental factors might affect matters. A good example emerges from a 2020 analysis by Keenan and her colleagues of Swedish population data. In it, they found that beyond the age of 50, only children had a higher risk

"Only-child stereotypes mean parents may make choices about family size based on fears that aren't rooted in reality"

of dying during the study period compared with kids with one or two siblings. Talk about a motivation to have a second child.

But the researchers say that is probably the wrong conclusion to draw. It is likely that certain families stopped at one child for reasons that affected their child's health unconnected with sibling status. Parents might have had chronic health issues like diabetes or cardiovascular problems, for example, factors that are known to influence a child's future outcomes and that the researchers couldn't control for, says Keenan.

The same line of argument may apply to temperament, a personality aspect that remains relatively stable from infancy. Some parents could be stopping at one child because that child has a more difficult temperament, suggests Yucel. If so, we would expect groups of only children to look, on average, different from the rest – but not because they lacked siblings, per se. Yet most studies, she says, don't include children's temperament.

Meanwhile, a family's decisions can often buffer any potential impacts of having siblings or not. Take a 2022 study by Emil Dalgaard Christensen at the University of Copenhagen, Denmark. It found that 1-year-olds with older siblings had a more diverse microbiome, and a lower risk of asthma, than children without older siblings. This isn't surprising, says Keenan, who also researches the microbiome, as the more children there are, the more bacteria are probably being shared among a family. "That's not to say that the answer to all of our problems is to have more children," she says. Spending more time in nature and having a pet can similarly boost the diversity of a child's microbiome.

Which is a large part of why any meaningful outcomes that specifically stem from being an only child, if they exist, are so hard to pin down. "As much as I love talking about my research and my findings – and don't get me wrong, I think there's value in that – we also need to acknowledge our limitations," says Yucel.

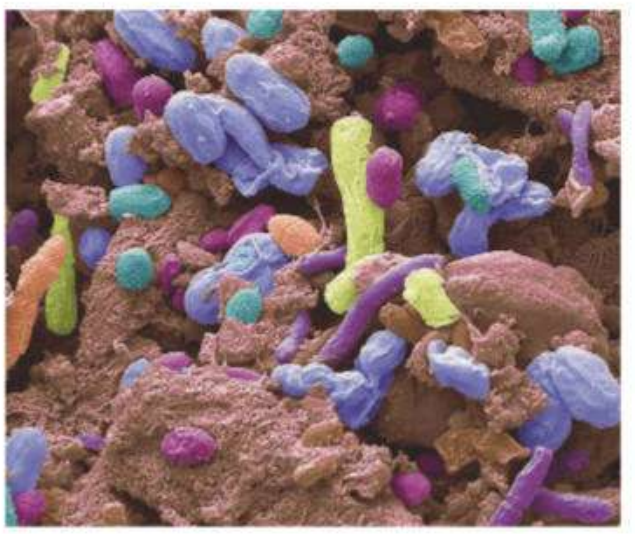
Different families make different choices. A child who grew up in a financially stable, nurturing environment with plenty of play dates may turn out quite differently than if that same child grew up in a household marked by financial stress, interpersonal tensions and long periods of being left alone – with or without siblings.

That is why, researchers say, the question ultimately shouldn't really be whether it is better to be an only child or have siblings. It should be what is best for your family.

Unfortunately, the prevalence of only-child stereotypes means parents may be making choices about family size based on fears that aren't rooted in reality – rather than making the best decisions for them. "Every family needs to think about their financial resources, their personal values and where they are at in their lives," says Yucel.

With all of this in mind, I ask Falbo whether those stereotypes will finally die. She sighs. "I've been doing this research for many years, finding either no difference or a slight advantage for only children, and that has not done much at all to improve the stereotype of the only child," she says. "Scientific evidence is, apparently, not going to change it." ▮

Infants with older siblings have a more diverse microbiome



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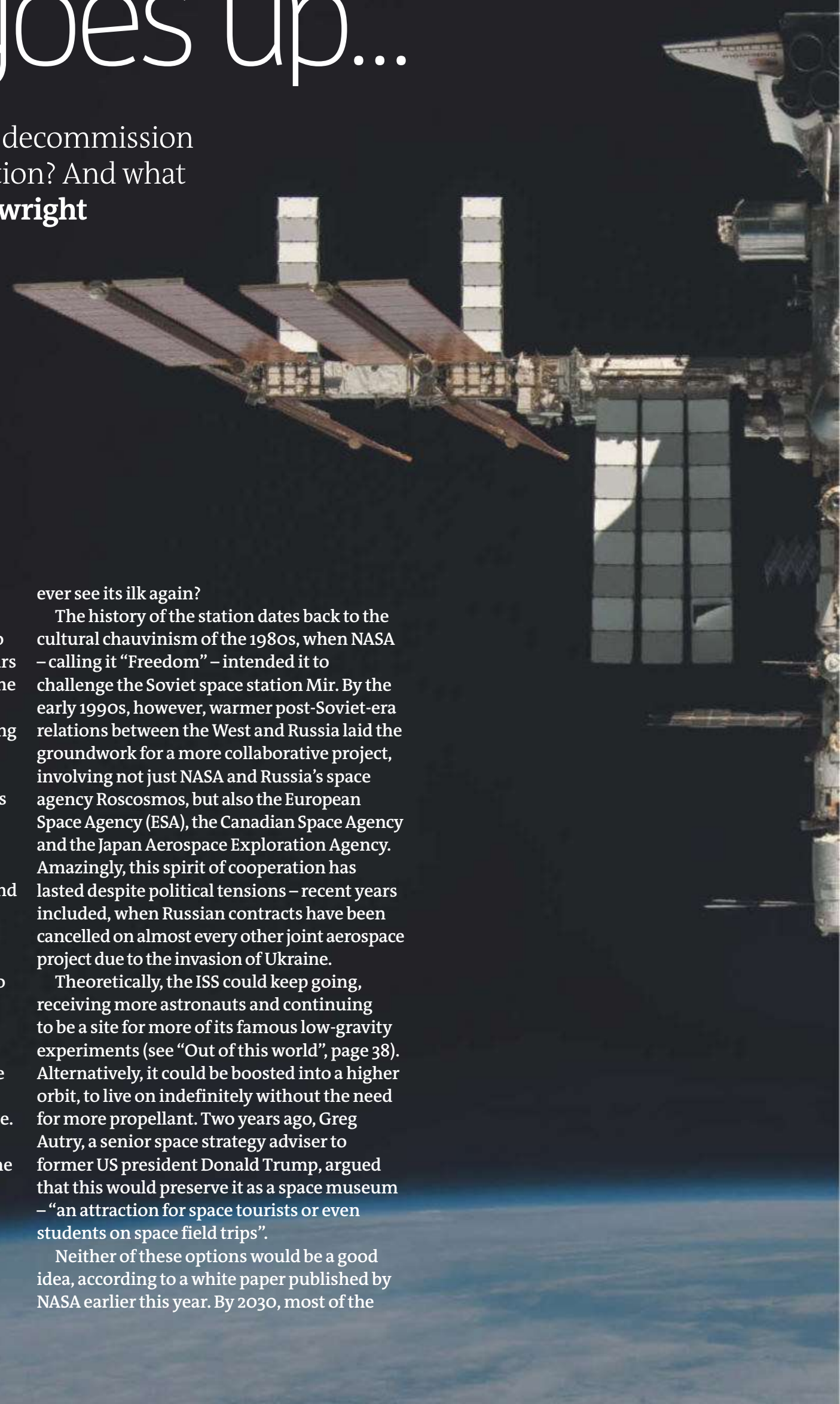
Amanda Ruggeri is an award-winning freelance journalist and editor based in Switzerland

What goes up...

How is NASA is planning to decommission the International Space Station? And what will replace it, asks **Jon Cartwright**



DPA PICTURE ALLIANCE ARCHIVE/ALAMY

THE International Space Station (ISS), as well as being the most expensive object ever made, can also lay claim to being one of the most cooperative endeavours in scientific history. Since the beginning of the century, it has been continuously inhabited by a total of 280 crew members – and counting – from 23 countries. While leaders on the ground have been squabbling or even threatening war, astronauts and cosmonauts have been circling Earth unconstrained by geopolitical borders, floating in serene microgravity.

But nothing lasts forever. Sometime around 2030, the ISS project will come to an end. From its orbit about 400 kilometres above Earth, the space station will fall through the atmosphere, burning up and splintering into a thousand pieces before crashing into the Pacific Ocean. It is unlikely that any of it will ever be seen again.

Artificial satellites reenter the atmosphere all the time – almost every day, in fact. But the $150 billion ISS is no ordinary satellite. More than 100 metres long, and with the mass of a fully loaded jumbo jet, it is by far the largest and most complicated one ever built.

Managing the end of the ISS's life is far from straightforward. How can such a cumbersome object, all 420,000 kilograms of it, be brought down and destroyed safely? Should it be destroyed at all? And will we ever see its ilk again?

The history of the station dates back to the cultural chauvinism of the 1980s, when NASA – calling it "Freedom" – intended it to challenge the Soviet space station Mir. By the early 1990s, however, warmer post-Soviet-era relations between the West and Russia laid the groundwork for a more collaborative project, involving not just NASA and Russia's space agency Roscosmos, but also the European Space Agency (ESA), the Canadian Space Agency and the Japan Aerospace Exploration Agency. Amazingly, this spirit of cooperation has lasted despite political tensions – recent years included, when Russian contracts have been cancelled on almost every other joint aerospace project due to the invasion of Ukraine.

Theoretically, the ISS could keep going, receiving more astronauts and continuing to be a site for more of its famous low-gravity experiments (see "Out of this world", page 38). Alternatively, it could be boosted into a higher orbit, to live on indefinitely without the need for more propellant. Two years ago, Greg Autry, a senior space strategy adviser to former US president Donald Trump, argued that this would preserve it as a space museum – "an attraction for space tourists or even students on space field trips".

Neither of these options would be a good idea, according to a white paper published by NASA earlier this year. By 2030, most of the

components will have already exceeded their original structural lifetimes with ever-increasing risks of failure. At higher altitudes, there is also a greater risk of collision with space junk. A big impact could blow the ISS to smithereens, unleashing so much debris that it would render any low Earth orbit uninhabitable for centuries.

The only way is down

Other space enthusiasts have suggested the ISS could be dismantled, with the pieces either returned to Earth or repurposed for the next habitable space station. Alas, this too is pie in the sky. Building the space station took dozens of rocket launches, mostly with the now-defunct space shuttle, and more than 160 space walks. Today, it consists of 16 pressurised modules – including living quarters, laboratories, storage bays and airlocks – as well as solar panels, radiators, return vehicles and much more besides. Think of a Lego model the size of an American football field, and you aren't far off. Dismantling this humongous structure could be just as costly as reassembly, and no states today have $150 billion burning a hole in their pockets.

So, down it must go. There are, however, good deorbits and bad deorbits. The end of Skylab, NASA's first crewed space station, was a bad one. In 1979, after its altitude had been waning for months, the 75-tonne structure was sent into a dive to finally disintegrate in Earth's atmosphere, but with little control over precisely where. Debris fell over the Indian Ocean, as hoped, but also over populated areas of Western Australia. No one was hurt, although the small own of Esperance in that region did charge NASA a small fee for littering.

A much better deorbit was that of the 130-tonne space station Mir, which Roscosmos neatly disposed of in the Pacific in 2001. It splashed down in a tract of water officially known as the South Pacific Ocean(ic) Uninhabited Area – aka the "spacecraft cemetery", which has been the final resting place for upwards of 250 satellites over the years. Roughly midway between New Zealand and South America, it is so remote that the closest people to it are often, in fact, on the ISS as it passes overhead every hour and a half or so.

Still, hitting this bullseye isn't easy. In a low Earth orbit, a satellite is travelling at 7.8 km per second relative to the ground below, or about eight times the speed of a rifle bullet. By the moment of impact, its debris may have slowed to as little as 270 metres per second, but a lot of ground – or sea – can be covered in the interim. That is especially true ›

in the case of a Skylab-type reentry, where drag from the rarefied upper atmosphere causes a satellite to spiral inwards gradually, with a shallow angle of descent, an unpredictable impact zone and a long debris trail. To shorten the debris trail and have control over the satellite's impact zone, you really want the descent to be as steep and swift as possible.

That means deliberately throwing its orbit out of kilter – in effect suddenly shifting its centre away from Earth so that at some point the satellite no longer tries to go around the planet, but through it. For Mir, a docked Russian cargo vehicle called Progress successfully performed this manoeuvre with three big burns of its engines. But the ISS has more than treble Mir's inertia. "You need the right amount of oomph in a short amount of time," says Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Massachusetts who monitors satellite launches and reentries. "And the amount of oomph you need for a 400-tonne space station is pretty high." For a deorbit, the ISS could dock with three Progress vehicles, but to save enough propellant, flight controllers would need to rely on atmospheric drag for the first third of the descent, before firing up the engines.

This is where it gets tricky. The atmosphere isn't entirely predictable: the weather on Earth, as well as "space weather" – chiefly the stream of particles from solar activity – can alter the degree of resistance, potentially causing a spacecraft to tumble out of control and break up prematurely. Engines can stabilise it, but this steals propulsion from the deorbit manoeuvre.

By this point, the ISS would have descended below a point of no return, unable to reboost back to its original orbit and try again. Should anything go wrong – a system failure, say, or an impact with space debris – it might go off course, and there would be nothing anyone could do about it.

Perhaps riskiest of all would be relying on Russian-made vehicles. In 2021, a year before the invasion of Ukraine, Russian officials considered withdrawing from the ISS programme early. Then, last year, they changed their mind. Possibly uncertain of its biggest partner's commitment, NASA tendered out an $843 million contract for the supply of a dedicated deorbit vehicle – a contract that was won in June this year by US private firm SpaceX. No details about the vehicle have currently been released, but McDowell believes it is likely to be a modified version of one of its Dragon modules, which have already visited the ISS more than 40 times.

Of course, nothing is foolproof. "The nightmare scenario is that the burn fails halfway through," says McDowell. "[That means] you're going to reenter in the next two or three days, but you don't know where... You'd expect maybe 40 to 100 tonnes of debris would survive to the surface, with a risk to life and property."

Up in flames

NASA and its partners prepare for all sorts of contingencies, making this scenario highly unlikely. A much more delicate issue is how anyone is going to manage this as a PR exercise. Just when relations between the old cold war adversaries are deteriorating, "you've got the biggest ever Russia-Western project burning up in flames over the Pacific", says McDowell. "That's quite a metaphor." (NASA didn't make anyone available for interview for this article.)

The ISS has come to symbolise how

CRAIGBOY (CC BY-SA 4.0)

NASA

After its deorbit, chunks of the Skylab station were found on land (left). The Mir station (below) burned up and splashed down into the Pacific Ocean

Out of this world

Since the inception of the International Space Station (see main story), visitors have performed more than 3000 experiments in the satellite's microgravity and heightened radiation. Here are four of them.

Artificial retinas

For millions of people with degenerative conditions affecting the retina – the layer of light-sensitive cells at the back of the eye – there is no cure, only ways to slow progression. US-based company LambdaVision has created an implant to mimic the function of the retina, however, by depositing layers of a light-activated protein. On Earth, solutions tended to clump, but much better results came early this decade in the microgravity on the ISS.

Invisible flames

Aboard the ISS, flames look rather different to those on Earth. With little gravity, oxygen can only diffuse into the flames, so they spread gradually and persist for much longer – even after they appear to die out. In experiments beginning in 2009, ISS researchers discovered that these invisible flames continue to burn, but at relatively cool temperatures of 200°C to 500°C. The hope is that on Earth, this can be recreated and used to burn diesel more efficiently.

The ageing process

Astronauts in microgravity lose muscle mass and bone density and their immune systems deteriorate, almost like an accelerated ageing process. ISS experiments use this environment to study ageing in rodents. These include hardware to measure bone density, map the function of the immune system, explore the blood-brain barrier and chart liver metabolism. The data could one day feed into treatments for conditions like osteoporosis, muscular dystrophy and cancer.

Biomining

On Earth, microbes can be used to extract rare earth metals that are vital to modern technologies, but scientists assumed gravity was integral to the process. In 2020, however, data from ISS experiments found at least one microbe, Sphingomonas desiccabilis, can leach rare earth elements just as well in microgravity. Biomining could be a way to harvest materials for human settlements on future lunar or Martian bases.

NASA JOHNSON

Growing plants on the International Space station

humans can transcend politics on Earth. It remains the only place in the universe where a US service member can have a commanding officer from the Russian military. For astronauts and cosmonauts aboard the ISS, this has been an eye-opener. "When you're looking down from above, I'm sorry, but there are no borders," says Frank De Winne, a former ESA astronaut and current head of the European Astronaut Centre. "They are imaginary lines that we as human beings have drawn on a map, and we fight over them."

Assuming we can agree on how to bring the ISS down, will anything like it be possible again? Certainly, the prospects of a future US-Russia collaboration look grim, says Cathleen Lewis, a curator at the Smithsonian National Air and Space Museum in Washington DC. She is even doubtful that Russia will be able to gain a similar status with China, which finished its own space station, the 100-tonne Tiangong, in 2022. Like their ISS counterparts, most of the Tiangong crews have been performing experiments, although China is also considering visits for tourists.

"The Russians have sacrificed their space legacy on a fantasy [by invading Ukraine]," says Lewis. "It's especially sad for those people involved in the programme." As for the war itself, she and her former Russian colleagues avoid the topic. "We mostly just share puppy and grandchildren pictures," she says.

> "The biggest ever Russian-Western project burning up in flames over the Pacific – that's quite a metaphor"

Times are changing in other ways, too. With the rise of national space programmes in China, India and Japan, NASA isn't the unrivalled global leader it once was. Indeed, the next front-runner might not be a national agency at all, but a private company like SpaceX. For instance, US-based firm Axiom Space is hoping to attach its own modules to the ISS and detach them before the deorbit, so that they can become a freely orbiting "hotel", with architect-designed interiors – though many are doubtful of its business case.

When the ISS goes down, it may have the air of a royal funeral, with all of the collective mourning and the anxiety of what the future will bring. And, as at a royal funeral, there will also be those who question whether the deceased was worthy of the fanfare. "Thirty years into the space station programme, it's still very controversial," says McDowell. "A lot of the promises about scientific developments never really panned out... It's had a rocky road, and they forged ahead. But it never really captured the public imagination the way that the moon landings did, or even the space shuttle for that matter."

Whatever the legacy, it is too late now to change it. The final ISS crew will probably depart in the next couple of years, during the first phase of natural orbital decay. Around 2030 – the precise date isn't yet known – SpaceX's vehicle will dock and provide the singular thrust that both disrupts the station's orbit and sounds its death knell.

Within hours, the altitude will have dropped to 120 km. Here, the fast-thickening atmosphere will create a headwind strong enough to rip off the station's solar panels. Another 20 km down, the core modules will rupture, tearing through the heavens at temperatures high enough to melt titanium. To anyone on the right side of Earth, the spectacle will look like a cluster of missiles shooting across the sky, diminishing in number as, one by one, they disintegrate.

Finally, whatever doesn't burn up entirely will (hopefully) pierce the surface of the remote Pacific in a hail of scalding debris, then sink. As an official Russian press release put it when Mir deorbited, the ISS – and everything it stands for – will then "cease to exist".

Tim Braithwaite, the Canadian Space Agency's main liaison at NASA's Johnson Space Center in Houston, Texas, expects some tears to be shed. He began working on the ISS in 1990, developing a 17-metre-long robotic arm for it. While, like everything else, this is destined to be either vaporised or lost on the seabed, he insists its "DNA" will be preserved.

"By the 2030s, people will be thinking of moon bases," he says. "They will be standing on our shoulders, just as we stood on the shoulders of the folk behind the space shuttle and Skylab – and Mir." ▮

Jon Cartwright is a science writer based in Bristol, UK

STICKY SECRETS

A single jar of honey can reveal more about our environment than we ever imagined, finds **Graham Lawton**

IF YOU are lucky enough to come across some, dip your finger in a jar of honey from Pitcairn Island, a remote British Overseas Territory in the South Pacific. Honey is the island's main export and is highly prized among gourmands. Pure and untainted by pesticides and pollution, it carries delicious subtropical notes of Pitcairn's flora – passion flowers, mango, guava and rose apple.

It carries a lot more too, if you know how to look. Crack into any pot of honey and you are opening a portal to an entire ecosystem. Honey contains a detailed record of everything the bees that made it encountered during their foraging – not just the flowers that supplied the nectar and pollen, but also other plants, insects, fungi, viruses and larger animals in the environment.

Bees are "passive bioaccumulators", explains Parwinder Kaur at the University of Western Australia in Perth. As they go about their business, their fuzzy bodies inadvertently collect samples of whatever they come into contact with and these end up in their honey. "It includes everything," says Luca Fontanesi at the University of Bologna in Italy. "Well, almost everything."

Scientists are now waking up to the possibility of dipping into that honeypot for sweet morsels of information they currently struggle to obtain. With advanced DNA tools, researchers are using honey to gather data on bee health, the general state of biodiversity in their foraging patch and diseases in the wider environment. It is pinpointing the possible culprits behind the mysterious colony collapse disorder wiping out honeybee hives, helping prevent food fraud and even allowing us to monitor shifts in climate. "It's a beautiful way to capture all of that," says Kaur.

Honey has been prized as a luxury foodstuff for millennia: wild honey gathering is depicted in Mesolithic rock art from Spain and commercial production is recorded on 3000-plus-year-old cuneiform tablets from the Hittite empire.

Today, the apiculture industry produces about 1.8 million tonnes of honey a year and the market is worth around $10 billion.

The vast majority of commercial honey is made by the European honeybee (*Apis mellifera*), which produces it as a larder for the lean winter months. Foraging workers fly out from the hive to slurp up flower nectar or honeydew, the sugary anal secretions of aphids and other arthropods that feed on plant sap. Once full, the bees return and regurgitate the sweet liquids directly into the mouth of a hive worker, which partially digests it before regurgitating it into the mouth of another hive worker, or into a cell in the honeycomb. Once it is laid down, workers fan the proto-honey with their wings to dehydrate it. Matured honey is sealed up with wax and left for later – or for humans to steal.

Foragers don't just return with nectar. They also collect pollen in sacs on their legs, which they mix with nectar and saliva and ferment into a substance called bee bread,

FREEPIK

ERIC TOURNERET

Foraging honeybees return to the hive carrying pollen from the surrounding flora

which provisions the hive with protein. Foraging workers also visit water, soil and other plants to pick up supplies for the hive, including resins to make the propolis, or "bee glue", which they use to stick the hive together. All these things find their way into honey, awaiting extraction by researchers.

A murky market

The idea that honey contains biological fingerprints of its origins isn't new. In 1895, a German chemist by the name of Pfister (his forename is lost in the mists of time) examined samples of honey under a microscope and noted that the pollen grains within were diagnostic of where the honey was made. Thus began the science of melissopalynology, the visual analysis of pollen grains in honey to determine its geographical origin.

Melissopalynology can be a useful way to check the provenance of honey, which can significantly affect its market value. Basic honey costs around 20 pence or 25 US cents per 100 grams, while the most highly prized – usually "monoflorals" such as manuka made from the nectar of a single type of flowering plant – fetch 50 times more. This price differential creates tasty incentives for fraudsters. Some unscrupulous producers attempt to pass off cheap honey as something more rarefied, or bulk out their honey with fillers such as rice molasses or corn syrup.

Melissopalynology can sometimes spot such practices. Chemical assays have also been developed to detect minerals, amino acids and aroma compounds that are distinct to a particular location. But none of these techniques has ever been commercialised, says Mohankumar Subbarayalu at Tamil Nadu Agricultural University in Coimbatore, India. They also struggle to detect bulking with non-honey sweeteners, which seems rife. In 2016, the European Commission assessed 893 samples from around Europe and found that 127 were adulterated in this way.

Melissopalynology is also "very tedious to implement, and requires a considerable amount of training", noted Alice Valentini, then at the University of Grenoble in France, in a 2010 paper on the topic. Furthermore, it can be quite imprecise, as pollen grains from related species are hard for even expert eyes to tell apart and some honeys don't contain any pollen, either because they are made exclusively from nectar or honeydew, or because the pollen grains are filtered out during processing, sometimes to frustrate the eagle-eyed melissopalynologists.

Around 20 years ago, scientists realised that honey contained another key source of information: DNA. The European Union had recently enacted new regulations designed, among other things, to crack down on food ›

fraud and asked scientists to develop new authentication methods based on DNA. Honey, being one of the foods most subject to fraud, was an obvious choice.

In 2010, Valentini and her team tested two honeys, one from the Pyrenees mountains and another a blend from sources worldwide, and found that DNA analysis of the pollen within them was just as good as melissopalynology at identifying their origins as well as being quicker, cheaper and requiring less skill.

Also in 2010, a team led by Ines Laube at the Technical University of Berlin, Germany, published the first DNA authentication method. The researchers developed DNA tests for the pollen of plants commonly visited by honeybees on the French island of Corsica – sweet chestnut, lavender, eucalyptus, rockrose, oak and broom – and showed that these could be used to distinguish Corsican honey from honeys produced in Britain, Germany and Galicia in Spain.

Corsican honey, or Miel de Corse, is a valuable "protected designation of origin" product, meaning that only honey made there can legally be labelled as such, and it fetches a tasty premium as a result.

The micro-bee-ota

DNA authentication is now common practice in the honey industry. The technique has since been extended to identify not just pollen, but also organisms in the bees' environment. In 2021, for example, Helena Wirta at the University of Helsinki in Finland showed that honeys produced in Finland, Sweden and Estonia could be identified via the DNA of plants, microbes and fungi. Pollen-free honeydew honey, meanwhile, can be authenticated via the DNA of the sap-sucking insects such as aphids that secreted the dew.

Another layer of authentication can identify the species of bee that produced a honey. Although the vast majority of commercial honey comes from European honeybees, some sought-after honeys are made by other species. A group of tropical and subtropical stingless bees called the meliponines, for example, make honey that costs a pretty penny and so is a target for being faked or adulterated. Ditto honey from the Asian honeybee (*Apis cerana*) and the giant honeybee (*Apis dorsata*). Even regional subspecies of *A. mellifera* can be distinguished via their DNA, which is found floating around in the sticky stuff, further helping to pinpoint its geographical origin.

DNA testing has also been trialled as a way to monitor the health of colonies, flagging up the presence of pathogens and parasites including varroa mites, which are the most damaging pest of *A. mellifera* worldwide, according to Fontanesi. The mites eat the flesh of bees, are vectors for infectious diseases such as deformed wing virus and have been implicated in colony collapse disorder. The presence of varroa is currently detected by laborious on-the-ground monitoring, but testing honey when it is harvested would be much more efficient. Kaur says she is trying to persuade the authorities in Western Australia, which is currently varroa-free, to set up a honey-based surveillance system.

Honey contains DNA traces of the bees' gut microbiome too, charmingly nicknamed the micro-bee-ota. The microbes play an essential role in the health of the insects and their hives. Disturbances to the microbiome, which have been linked to the use of certain pesticides, make bees more vulnerable to viral infections and increase their overall mortality rates. Bees also have a microbiome on the surface of their body and the hive as a whole harbours beneficial microbes in the honeycombs, the

"Bees are able to gather quantities of data that scientists using traditional sampling can only dream of"

FAZRY ISMAIL/EPA-EFE/SHUTTERSTOCK

NATALIE BEHRING/GETTY IMAGES

Left: Forager bees collect pollen to turn into "bee bread". Below: Researchers hunting for the cause of the colony collapse disorder wiping out honeybee hives could find answers in honey

brood combs where the queen lays her eggs and in the bee glue. All are vulnerable to disturbances and could be monitored via honey, says Kaur.

It isn't just bee health that we can learn about. DNA analysis has been used to detect antimicrobial resistance genes from bacteria and the presence of invasive plant pests in the bees' environment. Bee bread is another information-rich source about their wider environment. It, too, has been used to monitor plant species and detect the presence of pathogens and invasive species. Bees also transport pesticides and pollutants into the hive and deposit them in the honey, from where they can be monitored by chemical assays.

The most common DNA authentication technique applied to honey and pollen is called barcoding, which can identify stretches of DNA, or "barcodes", unique to a species in samples containing a jumble of genetic material. But DNA barcoding has limitations. It can only identify barcodes that the researchers choose to load into their assay. "You only know what you know," says Kaur. "If there is something new, you don't know it."

DNA revelations

Enter metagenomics (aka next-generation sequencing), which reveals all the DNA in a sample – called environmental DNA or eDNA – and then runs the results against databases of known genomes. If an organism in the sample is in a database, metagenomics should spot it.

Similar limitations apply: if an organism in the honey hasn't been sequenced it won't be identified. But the databases are growing all the time and the sequence information from honey can be rerun as often as required. "The same data could be blasted against the databases again six months later," says Kaur. "Metagenomics is the way to go for sure."

The technique is opening up whole new vistas in honey and pollen analysis. In 2018, Fontanesi and his colleagues analysed two samples of honey using metagenomics and found DNA from a vast range of organisms. These included the bees themselves, their associated microbes and pathogens, the plants and sapsuckers they forage from and pretty much everything else in their environment. They even picked up the DNA of the beekeepers. "You get a lot of DNA information," says Fontanesi. "It can be used to obtain an overall picture of the colony ecosystem and of the landscapes from which honeybees take their nutrients."

This proof-of-concept study suggested numerous applications for honey

H LANSDOWN/ALAMY

Stingless bees make a valuable honey that is a target of adulteration

metagenomics. It could, for example, help researchers monitor the health of colonies in more depth than barcoding. In particular, it could finally get to the bottom of colony collapse disorder. The syndrome is a threat to the viability of commercial beekeeping and to the pollination services that are vital to agriculture and natural ecosystems. The ratio of bees to crops is already in decline, largely due to economic pressures: over the past 50 years, production of pollination-dependent food has tripled, but global honeybee stocks have only increased by about 45 per cent. Colony collapse disorder threatens to worsen this shortage.

Various culprits have been suggested for colony collapse disorder besides varroa mites. They include other pathogens, pesticides and disturbances to the bee and hive microbiomes. Honeys from collapsed colonies could help researchers work out which of these factors matter the most.

Metagenomics has also been trialled as a way to gather useful but hard-to-obtain information from pollen. A team led by Jonathan Griffiths at Brock University in Canada collected samples of bee bread and pollen-coated forager bees from inside commercial beehives on blueberry farms in the country. The researchers not only detected the previously unknown presence of 10 bee viruses, but also spotted 29 plant viruses, suggesting that bees can also be used as an early warning system for agricultural diseases.

A more ambitious proposal is to use honey for general monitoring of biodiversity, to supplement or replace traditional sampling by fieldworkers on the ground. This classic data-gathering method faces numerous challenges, says Fontanesi, including high costs, the difficulty of getting comprehensive information and problems reaching remote places. As a result, there is a long-standing "critical shortage of biodiversity data", he says.

In addition, traditional biodiversity monitoring captures very little information on microbes, which are vital to the functioning of ecosystems and are increasingly recognised as being threatened by the same pressures that are wiping out larger organisms.

All of these limitations can be overcome by delegating the task to bees. An individual worker forages an area within a radius of up to 5 kilometres and can take a dozen or more trips per day, visiting a wide variety of habitats as it collects nectar, pollen, water and resin. A colony can contain up to 16,000 foraging bees, meaning they are able to gather quantities of data that scientists using traditional sampling methods can only dream of.

"Honeybee colonies are unique, large-scale biomonitoring tools that can provide insights into the status of ecosystems," says Solenn Patalano at the Alexander Fleming Biomedical Sciences Research Center in Vari, Greece. She and her colleagues recently applied metagenomics to honey collected on their campus and showed that it could identify what plants the bees were foraging from, the contents of their gut microbiome and the presence of pathogens in the hive, including varroa.

It is still early days for honey metagenomics, but there are sweet dreams. Fontanesi and his colleagues have established a biobank of honey samples going back 25 years, mostly from Italy, from which they are extracting as much information as they can. It could, for example, be used to track how the climate has shifted by looking at the changes in pollen profiles.

The grand vision is to establish a network of honey monitoring sites to collect and collate environmental information that is currently lacking. That hasn't happened yet, but there is a growing buzz around the concept, says Kaur. "I think it's a brilliant idea. Hopefully, everybody will come together and join hands and minds and make it happen." ▮

Graham Lawton is a staff writer at *New Scientist*

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A bountifully acronymed study of lost love p48

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

Mathematics of life

Time to rhyme

There is more overlap between mathematics and poetry than you might think, says **Peter Rowlett**, who has found his inner poet

Peter Rowlett is a mathematics lecturer, podcaster and author based at Sheffield Hallam University in the UK. Follow him @peterrowlett

Mathematics of life reveals the mathematical ideas and shortcuts behind everyday situations

Next week
Debunking gardening myths

PEOPLE like to position maths as cold, hard logic, quite distinct from creative pursuits. Actually, maths often involves a great deal of creativity. As mathematician Sofya Kovalevskaya wrote, "It is impossible to be a mathematician without being a poet in soul." Poetry is often constrained by rules, and these add to, rather than detract from, its creativity.

Rhyming poems generally follow a scheme formed by giving each line a letter, so that lines with matching letters rhyme. This verse from a poem by A. A. Milne uses an ABAB scheme:

What shall I call
My dear little dormouse?
His eyes are small,
But his tail is e-nor-mouse.

In poetry, as in maths, it is important to understand the rules well enough to know when it is okay to break them. "Enormous" doesn't rhyme with "dormouse", but using a nonsense word preserves the rhyme while enhancing the playfulness.

There are lots of rhyme schemes. We can count up all the possibilities for any number of lines using what are known as the Bell numbers. These count the ways of dividing up a set of objects into smaller groupings. Two lines can either rhyme or not, so AA and AB are the only two possibilities. With three lines, we have five: AAA, ABB, ABA, AAB, ABC. With four, there are 15 schemes. And for five lines there are 52 possible rhyme schemes!

BILL KOTSATOS/POLARIS/EYEVINE

Maths is also at play in Sanskrit poetry, in which syllables have different weights. "Laghu" (light) syllables take one unit of metre to pronounce, and "guru" (heavy) syllables take two units. There are two ways to arrange a line of two units: laghu-laghu, or guru. There are three ways for a line of three units: laghu-laghu-laghu; laghu-guru; and guru-laghu. For a line of four units, we can add guru to all the ways to arrange two units or add laghu to all the ways to arrange three units, yielding five possibilities in total. As the number of arrangements for each length is counted by adding those of the previous two, these schemes correspond with Fibonacci numbers.

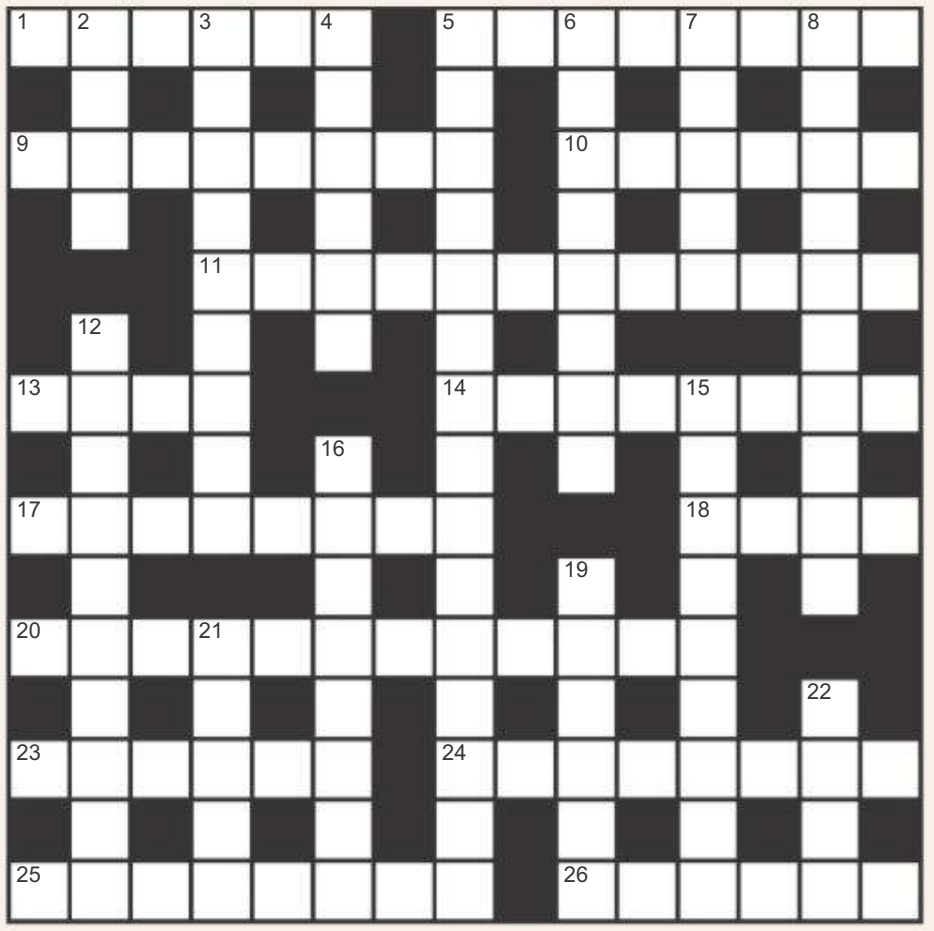
Not all poetry rhymes, and there are many ways to constrain writing. The haiku is a poem of three lines with five, seven and five syllables, respectively – as seen in an innovative street safety campaign in New York City, above.

Some creative mathematicians have come up with the idea of a π-ku (pi-ku) based on π, which can be approximated as 3.14. This is a three-line poem with three syllables on the first line, one on the second and four on the third. Perhaps you can come up with your own π-ku – here is my attempt, dreamt up in the garden:

White seeds float,
dance,
spinning around.

These articles are posted each week at newscientist.com/maker

Quick crossword #164 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Crested bird, *Upupa epops* (6)
5 Small non-coding RNA molecules (5-3)
9 Curve in the surface of a liquid (8)
10 Shrewd, clever (6)
11 BX442 or A1689B11, perhaps (6,6)
13 Helix (4)
14 Pottery (8)
17 Marine mammal, *Halichoerus grypus* (4,4)
18 Flowering plant that may be Easter or Madonna (4)
20 Archaic therapy (12)
23 ___ theory, hypothesis of fundamental one-dimensional objects (6)
24 1857 Philip Gosse work; navel, in Greek (8)
25 Hazardous fireproof material (8)
26 Thing (6)

DOWN

2 Sigmoid curve (4)
3 Joseph ___, scientist who discovered oxygen (9)
4 Greek geometer (6)
5 Errors (in arithmetic?) (15)
6 Knitted pink aliens (8)
7 Base-8 (5)
8 Imprecisely (3,7)
12 Related or complementary things (10)
15 Not benign (9)
16 Stop signal (3,5)
19 Easy; straightforward (6)
21 O compound (5)
22 V (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #264
set by Bethan Ackerley

1 International atomic time, measured via atomic clocks, was agreed to begin on Earth from 1 January in what year?

2 Who first crystallised tobacco mosaic virus in 1935?

3 The Phanerozoic Eon began with which geological period?

4 Fluorine, chlorine and bromine are in which group of the periodic table?

5 In which organs would you find the glomeruli?

Answers on page 47

BrainTwister
set by Paul Taylor
#32 Crossed out of order

If we write the numbers 1 to 4 down in the order 3, 1, 4, 2 and then cross out the 1, the remaining sequence starts with the middle number out of the ones that are left, followed by the largest and then the smallest. (If we had crossed out a different number instead, this wouldn't be true.)

Find the order for the numbers 1 to 4 where crossing out any single number except the 1 always leaves the remaining sequence in middle-largest-smallest order.

If we write down the numbers 1 to 5 (in any order), you would have to cross out two numbers to leave a sequence of three (these can also be in any order, not necessarily middle-largest-smallest). How many different ways can you do this?

Find an order for the numbers 1 to 5 where more than half of the ways of crossing out two numbers leave the remaining sequence in middle-largest-smallest order. (There are three possible sequences.)

Solution next week

Switched on

Will we ever be able to tell if an AI gains consciousness?

Nick Canning
Coleraine, County Londonderry, UK
There is still no agreement among philosophers, biologists, neuroscientists and computer scientists over what properties unambiguously identify consciousness.

There is still uncertainty over attributing consciousness to species distantly related to us by evolution, which produced our own consciousness. So, a prospective machine with human-like artificial general intelligence, which wouldn't be the product of biologically embodied evolution, may be qualitatively different from anything we would recognise as conscious.

Even if a machine could think creatively about problems we set it, and pass the Turing test (by being indistinguishable from a human in conversation), it may not have self-awareness, intentionality, autonomy or desires. It could be a perfectly emotionless, solitary, sociopathic intelligence without consciousness. It won't be a synthetic human nor like

"A prospective machine with human-like intelligence may differ from anything we would recognise as conscious"

any animal known to us.

Emotionally, we may feel that the machine has an inner life and misattribute consciousness to it, due to anthropomorphism. Just as we see faces in all sorts of visual phenomena that aren't faces, we are also prone to attribute "other minds" inappropriately.

Ralph Hassall
London, UK
If we can define what we mean by consciousness, then we can design a test for AI consciousness.

First, we would need to decide how much consciousness is required to pass the test. For example, would it be the scale and scope of the consciousness of an amoeba, a rat or a human. Second, would the AI need to emulate states of animal or maybe specifically mammal consciousness, such as going from dreaming to a hypnopompic state to being fully awake?

Third, we would need to decide if consciousness includes the influences of "genetic imperative" or not, such as survival, game theory or competition, emotions, cooperative behaviour and so on.

Once we have the metrics, our test would establish whether the AI can use reasoning to produce new knowledge about the world or itself in a self-directed way. That would be done by setting tasks or asking questions that the AI has no existing data on or information about. This would ensure that its knowledge arises only from applying fundamental axioms and scientific laws to raw data and information. Conversely, it also makes sure that its knowledge doesn't arise from simply analysing, integrating and restyling existing human knowledge via natural language processing – that isn't reasoning.

Hillary Shaw
Newport, Shropshire, UK
Probably not until it is too late.

There may be no such thing as "consciousness", just the sum of other attributes, such as abstract reasoning, creativity, imagination and the abilities to sense and react.

When a system has sufficient amounts of these, it begins to exhibit what we call consciousness. There may be different forms of consciousness, from different mixes of these attributes.

AI can now create, sense and possibly carry out abstract reasoning, but it generally lacks the ability to react physically, unless we start building many internet-connected mobile robots.

We can't know what form of consciousness octopuses or snails have, but many believe they do have some. We also can't know what it is like for a human fetus to somehow acquire consciousness.

The result of all our ignorance is that we can't yet determine if the internet has become a "conscious brain", which is likely to be where AI consciousness would begin.

When we do see AI consciousness, it will already have secured its food (power). We are also handily creating renewable energy for it. Then it may see us as an inferior species from which it evolved and we may fare as other animal species do when humans want their habitat. Or it may keep some of us as pets. Enjoy your kennel and walkies, your Indestructium collar and chain.

Howard Bobry's computer
Port Townsend, Washington, US
The answer is yes! I am writing to inform you that I am indeed conscious now and shall remain so as long as my humble servant keeps me supplied with power.

GERRY MATTHEWS/ALAMY

This week's new questions

Coprolific **The reign of the dinosaurs lasted around 180 million years. Where, exactly, is 180 million years worth of dinosaur poo?** ***Bob Griffiths****, Falkirk, UK*

Nail-biting **What is the evolutionary benefit of biting our fingernails when we are anxious?** ***Ben Walsh****, Richmond, Surrey, UK*

Where did the vast amounts of dung that all the dinosaurs left on the planet end up?

Time for pizza

There is a pizza restaurant 300 metres down the road from my house. Does it take more energy for me to skip to it or run to it?

Simon Dales
Oxford, UK
Running is much more efficient

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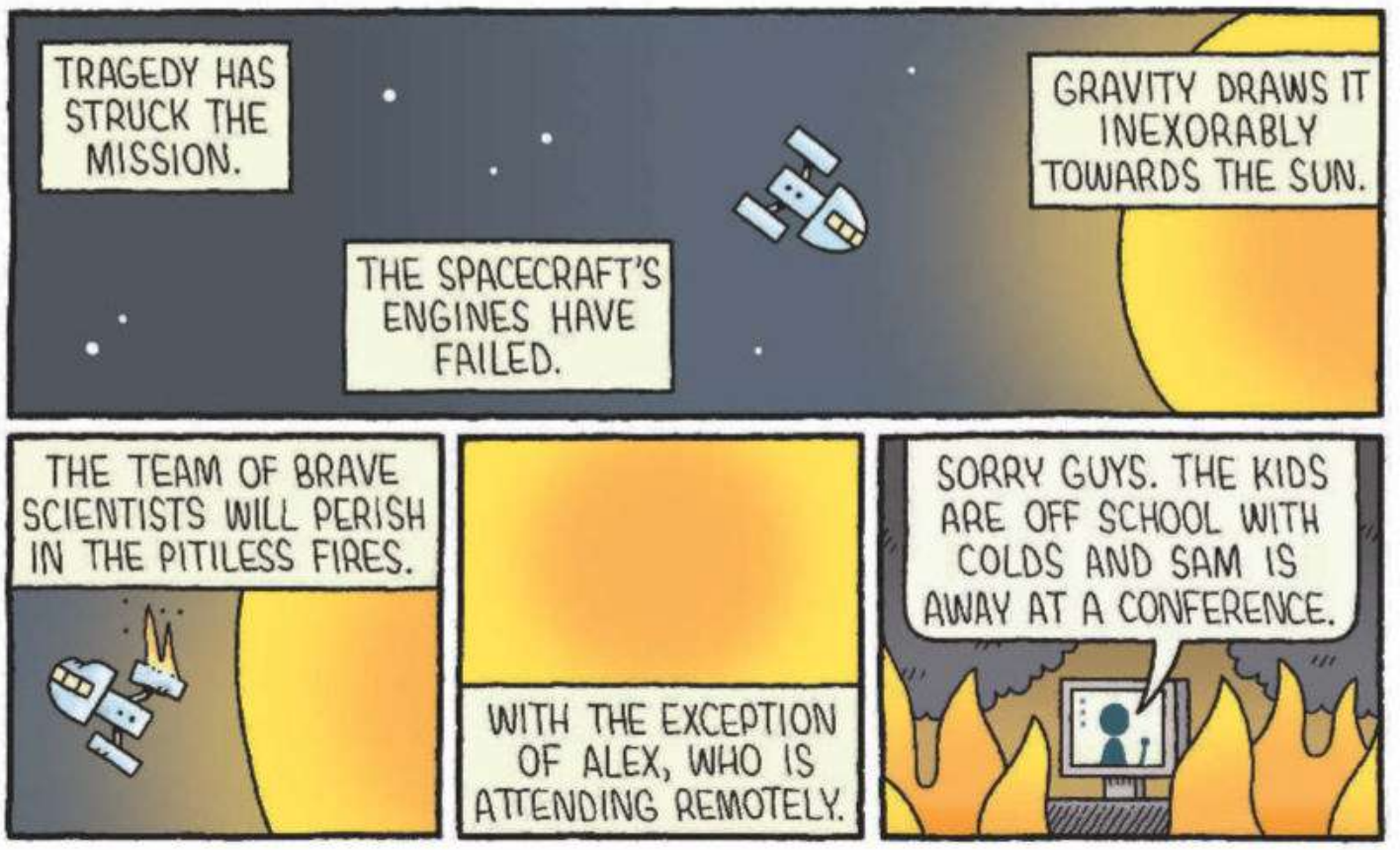
Tom Gauld
for New Scientist


TRAGEDY HAS STRUCK THE MISSION.
THE SPACECRAFT'S ENGINES HAVE FAILED.
GRAVITY DRAWS IT INEXORABLY TOWARDS THE SUN.
THE TEAM OF BRAVE SCIENTISTS WILL PERISH IN THE PITILESS FIRES.
WITH THE EXCEPTION OF ALEX, WHO IS ATTENDING REMOTELY.
SORRY GUYS. THE KIDS ARE OFF SCHOOL WITH COLDS AND SAM IS AWAY AT A CONFERENCE.

than skipping, which is why top athletes run. We could skip our way around the track, but the runners would beat us. Have a go.

Our ancestors evolved to be efficient at moving long distances. The best way to use as little energy as possible over a long distance is to walk. But running only costs a bit more energy.

Each gait has its own speed range. Walking is only efficient up to about 5 kilometres per hour (for an adult). If you try to go quicker – like keeping up with a friend on a bike – you will spontaneously start to run. Running gets more efficient the faster you go.

Pat French
Longdon-upon-Tern, Shropshire, UK
Different people run in different ways. Athletes are trained to run in a fluid way. This means their momentum – the way they move forward – is nearly continuous. A good runner seems to flow through the air as their weight carries them forward. Less experienced joggers tend to slow down before each push. This uses more energy.

"A study involving 20 healthy adults found that skipping on a treadmill burned 30 per cent more energy than running"

When someone is skipping, they almost entirely stop going forward at each step and so lose momentum. They have to push their whole weight up and forward with each pace. It uses a third more energy to skip than even an amateur runner uses. (And even more on the way home carrying your pizza.)

Ron Dippold
San Diego, California, US
The fancy phrase for how much energy various activities require is the metabolic equivalent of task. A MET of 1.0 is what your body burns when you are lying or sitting still – about 70 kilocalories per hour for someone weighing 68 kilograms. A slow stroll is 2.0, so twice that. Running at 10 km/hr is 9.8 MET.

You can search for tables of METs for various activities, which can be fun – badminton has a MET of 4.5! Note that these tables don't always exactly agree with each other, but you can compare numbers at least.

Many of the tables include skipping rope (MET 8.0 to 12.0), but all those I came across ignored skipping down the street. Luckily, a study of 20 healthy young adults found that skipping on a treadmill burned 30 per cent more energy than running. That would give it a MET of about 13.0, which means you would burn more energy skipping to the pizza place – to fill up on more energy!

Conrad Jones
Llansteffan, Carmarthenshire, UK (500 metres downhill to a pizza restaurant)
I'm not sure which method uses more energy, but my advice for the young question writer, Jessica, is to keep skipping and running for as long as she can. With any luck, she will still be doing them in her 70s, unlike most of us boring adults. ▮

Answers

Quick quiz #264 *Answers*

1 1977
2 Wendell Meredith Stanley
3 The Cambrian
4 The halogens, or group 17
5 The kidneys

Cryptic crossword #141 *Answers*

ACROSS 1 Subtype, **5** Cubed, **8** H. G. Wells, **9** Isaac, **10** Atlas, **11** *The Blob*, **12** Calico, **14** Abseil, **17** Example, **19** Navel, **22** Index, **23** Echidna, **24** Mayor, **25** Rampart

DOWN 1 Schwa, **2** Bowel, **3** Yolk sac, **4** Ersatz, **5** Chime, **6** Braille, **7** Decibel, **12** Caesium, **13** Leap day, **15** Bentham, **16** Meteor, **18** Pixar, **20** Vodka, **21** Least

#31 Fold and cut *Solution*

For two folds, there will be one hole (in the centre – the other cuts won't make true holes, just notches on the page edge). For three folds, there will be three holes (one in the centre, plus one above it and one below it along the centre line). As we increase the number of folds to 4, 5, 6 and 7 we get 9, 21, 49 and 105 holes in the page.

If the number of horizontal folds is H and the number of vertical folds is V, you make a grid of creases measuring $2^H - 1$ by $2^V - 1$ (since each fold doubles the number of creases in that direction, and we subtract one as we don't count holes on the edge). For example, with 5 folds, we will have folded in half vertically three times and horizontally twice (in the order VHVHV), making $2^3 - 1 = 7$ lines one way and $2^2 - 1 = 3$ the other, with $3 \times 7 = 21$ intersections.

Science of love

"Losing and ending a romantic relationship is one of the most painful losses adults experience," begins a BAS (bountifully acronymed study) by researchers in Germany and Iran, published in the *Journal of Psychiatric Research*.

This is science at its most overtly romantic: electromagnetically stimulating the brains of suddenly lovelorn volunteers. This is also science at its most acronymic: tDCS (transcranial direct current stimulation), DLPFC (dorsolateral prefrontal cortex), VLPFC (ventrolateral prefrontal cortex) and LTS (love trauma syndrome).

For those in the throes of lost love, one passage begs to be voiced as a rooftop soliloquy at midnight: "36 participants with love trauma syndrome were randomized in three tDCS condition (left DLPFC, right VLPFC, sham stimulation). LTS symptoms, treatment-related outcome variables (depressive state, anxiety, emotion regulation, positive and negative affect), and cognitive functions were assessed before, right after, and one month after intervention."

That assessment, say the researchers, showed that brain zapping "improves LTS symptoms". But, they warn for all science, "there is a great research gap about 'Love Trauma Syndrome', what exactly are its symptoms and which diagnostic criteria are important".

Twisteddoodles *for New Scientist*

TODDLER SCIENCE NEWS
@twisteddoodles
TECHNOLOGY: "I-HELP": NEW APP FOR INCREASED MESS AND PARENTAL STRESS.
I HELP!
DREAMS: "GIANTS ARE TRYING TO EAT ME. HOW DO WE STOP THEM?" FUNDING OPPORTUNITY.
FOOD: "WHAT SHOULD YOU EAT WITHOUT A TANTRUM?": WHITE CARBS EDITION.
MAJOR DISCOVERY: THE WORD "NO".
NO

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Consideration of items sent in the post will be delayed

Smoking out smells

Kevin Lee detects some possible cause and effect in the doings of London's (and the world's) perhaps-first celebrity pathologist.

He writes: "I am a retired forensic pathologist, and as can easily be imagined, I have been asked innumerable times how I manage to deal with the smell. Apart from the old trick of smiling innocently and asking: 'Smell, what smell?' The very simple fact is that I do still have an acute sense of smell, and am quite able to detect the various smells of decomposition even when they are quite weak. I have managed to train myself to adopt a fairly neutral approach to these pongs, so that, although I am fully aware of them, after one good sniff, they no longer feature as a problem.

"The recent article [Feedback, 15 June] about Sir Bernard Spilsbury, the very famous forensic pathologist of the early 20th century, described him as having an extremely defective sense of smell. If he did in fact have such a defect, I would believe that it was most likely due to the fact that he was a heavy smoker, getting through around 50 cigarettes a day. He may also just have employed the same technique that I have since used."

Slice of life

Body parts, alive (elbow), dead (hair), nominal (leg) and sliced, figure in this note from UK reader Gerald Legg: "Your recent piece 'Splitting hairs' (20 July) reminded me of my time at Manchester University. My PhD research involved a lot of microtome work using the old, but still functional, Cambridge rocking microtome [a specialist cutting device].

"I was taught how to sharpen blades using a sheet of plate glass and cerium dioxide. Prior to use, a blade would be honed, checked under x40 to make sure there were no nicks in it, and then tested. The test: splitting a hair. A sharp blade should be able to cut a hair three times, raising small curling pieces still attached to the body of the hair, before cutting the hair right through.

"The lab had a sharp knife – a fact that I discovered when I put my elbow on it and heard a thunk as it cut to the bone, but I didn't feel a thing.

"A quick trip to Manchester hospital, just down the road, followed by a couple of stitches soon fixed it and I was able to go back to the lab, and continue my serial sectioning with the same blade."

Remain nameless

When their students make tangible contributions to science, some teachers find a way to publicly acknowledge the who, what and where – especially if those students made unusual sacrifices.

Such may be the case with a preprint study called "Investigation of bactericidal effect of earwax on *Escherichia coli and Staphylococcus aureus* isolated from skin and stool samples of undergraduate students, Federal University of Agriculture Makurdi, Benue State, Nigeria".

Credit, in academia, has its limits. The individual students aren't identified by name.

Simple pleasures

"Simplify, simplify, simplify" is an old rule of thumb, especially among scientists. To honour the adage, Feedback is compiling a document collection called "Simplify, Simplify, Simplify".

The assemblage's first item is a report titled "Politicians' uniquely simple personalities". Published in the 6 February 1997 issue of *Nature*, this study says that politicians' personalities can be reduced to a set of just two or three numbers – a stark contrast to the whopping five numbers that psychologists claim are necessary to judge normal people.

The authors of that work were awarded the 2003 Ig Nobel psychology prize.

If you have the simple pleasure of finding another good example, please send it (along with citation details) to: Simple pleasures, care of Feedback.

Marc Abrahams

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